AIR FORCE
14.1 Small Business Innovation Research (SBIR)
Proposal Submission Instructions

INTRODUCTION

The Air Force (AF) proposal submission instructions are intended to clarify the Department of Defense (DoD) instructions as they apply to AF requirements.

The Air Force Research Laboratory (AFRL), Wright-Patterson Air Force Base, Ohio, is responsible for the implementation and management of the AF Small Business Innovation Research (SBIR) Program.

The AF Program Manager is Mr. David Sikora, 1-800-222-0336. For general inquiries or problems with the electronic submission, contact the DoD Help Desk at 1-866-724-7457 (1-866-SBIRHLP) (8:00 a.m. to 5:00 p.m. ET Monday through Friday). For technical questions about the topics during the pre-solicitation period (20 November through 19 December 2013), contact the Topic Authors listed for each topic on the Web site. For information on obtaining answers to your technical questions during the formal solicitation period (20 December 2013 through 22 January 2014), go to http://www.dodsbir.net/sitis/.

General information related to the AF Small Business Program can be found at the AF Small Business website, http://www.airforcesmallbiz.org. The site contains information related to contracting opportunities within the AF, as well as business information, and upcoming outreach/conference events. Other informative sites include those for the Small Business Administration (SBA), www.sba.gov, and the Procurement Technical Assistance Centers, www.aptacus.org/new/Govt_Contracting/index.php. These centers provide Government contracting assistance and guidance to small businesses, generally at no cost.

The AF SBIR Program is a mission-oriented program that integrates the needs and requirements of the AF through R&D topics that have military and/or commercial potential.

PHASE I PROPOSAL SUBMISSION

Read the DoD program solicitation at www.dodsbir.net/solicitation for program requirements. When you prepare your proposal, keep in mind that Phase I should address the feasibility of a solution to the topic. For the AF, the contract period of performance for Phase I shall be nine (9) months, and the award shall not exceed $150,000. We will accept only one Cost Volume per Topic Proposal and it must address the entire nine-month contract period of performance.

The Phase I award winners must accomplish the majority of their primary research during the first six months of the contract. Each AF organization may request Phase II proposals prior to the completion of the first six months of the contract based upon an evaluation of the contractor's technical progress and review by the AF technical point of contact utilizing the criteria in section 6.0 of the DoD solicitation. The last three months of the nine-month Phase I contract will provide project continuity for all Phase II award winners so no modification to the Phase I contract should be necessary.

The Phase I Technical Volume has a 20-page-limit (excluding the Cover Sheet, Cost Volume, Cost Volume Itemized Listing (a-k), and Company Commercialization Report).

Limitations on Length of Proposal

The Technical Volume must be no more than 20 pages (no type smaller than 10-point on standard 8-1/2" x 11" paper with one (1) inch margins. The Cover Sheet, Cost Volume, Cost Volume Itemized Listing (a-k), and Company Commercialization Report are excluded from the 20 page limit. Only the Technical Volume and any enclosures or attachments count toward the 20-page limit. In the interest of equity, pages in excess of the 20-page limitation (including attachments, appendices, or references, but excluding the Cover Sheet, Cost Volume, Cost Volume Itemized Listing (a-k), and Company Commercialization Report, will not be considered for review or award.

Phase I Proposal Format

Proposal Cover Sheets: The Cover Sheet does NOT count toward the 20 page total limit. If your proposal is selected for award, the technical abstract and discussion of anticipated benefits will be publicly released on the Internet; therefore, do not include proprietary information in these sections.

Technical Volume: The Technical Volume should include all graphics and attachments but should not include the Cover Sheet or Company Commercialization Report (as these items are completed separately). Most proposals will be printed out on black and white printers so make sure all graphics are distinguishable in black and white. It is strongly encouraged that you perform a virus check on each submission to avoid complications or delays in submitting your Technical Volume. To verify that your proposal has been received, click on the "Check Upload" icon to view your proposal. Typically, your uploaded file will be virus checked. However, if your proposal does not appear after an hour, please contact the DoD Help Desk at 1-866-724-7457 (8:00 am to 5:00 pm ET Monday through Friday).

Key Personnel: Identify in the Technical Volume all key personnel who will be involved in this project; include information on directly related education, experience, and citizenship. A technical resume of the principle investigator, including a list of publications, if any, must be part of that information. Concise technical resumes for subcontractors and consultants, if any, are also useful. You must identify all U.S. permanent residents to be involved in the project as direct employees, subcontractors, or consultants. You must also identify all non-U.S. citizens expected to be involved in the project as direct employees, subcontractors, or consultants. For all non-U.S. citizens, in addition to technical resumes, please provide countries of origin, the type of visa or work permit under which they are performing and an explanation of their anticipated level of involvement on this project, as appropriate. You may be asked to provide additional information during negotiations in order to verify the foreign citizen's eligibility to participate on a contract issued as a result of this solicitation.

Voluntary Protection Program (VPP): VPP promotes effective worksite-based safety and health. In the VPP, management, labor, and the Occupational Safety and Health Agency (OSHA) establish cooperative relationships at workplaces that have implemented a comprehensive safety and health management system. Approval into the VPP is OSHA's official recognition of the outstanding efforts of employers and employees who have achieved exemplary occupational safety and health. An "Applicable Contractor" under the VPP is defined as a construction or services contractor with employees working at least 1,000 hours at the site in any calendar quarter within the last 12 months that is NOT directly supervised by the applicant (installation). The definition flows down to affected subcontractors. Applicable contractors will be required to submit Days Away, Restricted, and Transfer (DART) and Total Case Incident (TCIR) rates for the past three years as part of the proposal. Pages associated with this information will NOT contribute to the overall Technical Volume page count. NOTE: If award of your firm's proposal does NOT create a situation wherein performance on one Government installation will exceed 1,000 hours in one calendar quarter, **SUBMISSION OF TCIR/DART DATA IS NOT REQUIRED.**

Phase I Work Plan Outline

NOTE: THE AF USES THE WORK PLAN OUTLINE AS THE INITIAL DRAFT OF THE PHASE I STATEMENT OF WORK (SOW). THEREFORE, DO NOT INCLUDE PROPRIETARY INFORMATION IN THE WORK PLAN OUTLINE. TO DO SO WILL NECESSITATE A REQUEST FOR REVISION AND MAY DELAY CONTRACT AWARD.

At the beginning of your proposal work plan section, include an outline of the work plan in the following format:

1) Scope
   List the major requirements and specifications of the effort.
2) Task Outline
   Provide a brief outline of the work to be accomplished over the span of the Phase I effort.
3) Milestone Schedule
4) Deliverables
   a. Kickoff meeting within 30 days of contract start
   b. Progress reports
   c. Technical review within 6 months
   d. Final report with SF 298

Cost Volume

Cost Volume information should be provided by completing the on-line Cost Volume form and including the Cost Volume Itemized Listing (a-k) specified below. The Cost Volume detail must be adequate to enable Air Force personnel to determine the purpose, necessity and reasonability of each cost element. Provide sufficient information (a-k below) on how funds will be used if the contract is awarded. The on-line Cost Volume and Itemized Cost Volume Information (a-k) will not count against the 20-page limit. The itemized listing may be placed in the "Explanatory Material" section of the on-line Cost Volume form (if enough room), or as the last page(s) of the Technical Volume Upload. (Note: Only one file can be uploaded to the DoD Submission Site). Ensure that this file includes your complete Technical Volume and the Cost Volume Itemized Listing (a-k) information.

a. Special Tooling and Test Equipment and Material: The inclusion of equipment and materials will be carefully reviewed relative to need and appropriateness of the work proposed. The purchase of special tooling and test equipment must, in the opinion of the Contracting Officer, be advantageous to the Government and relate directly to the specific effort. They may include such items as innovative instrumentation and/or automatic test equipment.

b. Direct Cost Materials: Justify costs for materials, parts, and supplies with an itemized list containing types, quantities, and price and where appropriate, purposes.

c. Other Direct Costs: This category of costs includes specialized services such as machining or milling, special testing or analysis, costs incurred in obtaining temporary use of specialized equipment. Proposals, which include leased hardware, must provide an adequate lease vs. purchase justification or rational.

d. Direct Labor: Identify key personnel by name if possible or by labor category if specific names are not available. The number of hours, labor overhead and/or fringe benefits and actual hourly rates for each individual are also necessary.

e. Travel: Travel costs must relate to the needs of the project. Break out travel cost by trip, with the number of travelers, airfare, per diem, lodging, etc. The number of trips required, as well as the destination and purpose of each trip should be reflected. Recommend budgeting at least one (1) trip to the Air Force location managing the contract.

f. Cost Sharing: Cost sharing is permitted. However, cost sharing is not required nor will it be an evaluation factor in the consideration of a proposal. Please note that cost share contracts do not allow fees. NOTE: Subcontract arrangements involving provision of Independent Research and Development (IR&D) support are prohibited in accordance with Under Secretary of Defense (USD) memorandum "Contractor Cost Share", dated 16 May 2001, as implemented by SAF/AQ memorandum, same title, dated 11 Jul 2001.

g. Subcontracts: Involvement of university or other consultants in the planning and/or research stages of the project may be appropriate. If the offeror intends such involvement, describe in detail and include information in the Cost Volume. The proposed total of all consultant fees, facility leases or usage fees, and other subcontract or purchase agreements may not exceed one-third of the total contract price or cost, unless otherwise approved in writing by the Contracting Officer. Support subcontract costs with copies of the subcontract agreements. The supporting agreement documents must adequately describe the work to be performed (i.e., Cost Volume). At a minimum, an offeror must include a Statement of Work (SOW) with a corresponding detailed Cost Volume for each planned subcontract.

h. Consultants: Provide a separate agreement letter for each consultant. The letter should briefly state what service or assistance will be provided, the number of hours required and hourly rate.

i. Any exceptions to the model Phase I purchase order (P.O.) found at https://www.afsbirsttr.com/Proposals/Default.aspx (see "NOTE" within "Phase I Proposal Submission Checklist" section, p. AF-5).

j. DD Form 2345: For proposals submitted under export-controlled topics (either International Traffic in Arms (ITAR) or Export Administration Regulations (EAR)), a copy of the certified DD Form 2345, Militarily Critical Technical Data Agreement, or evidence of application submission must be included. The form, instructions, and FAQs may be found at the United States/Canada Joint Certification Program website, http://www.dlis.dla.mil/jcp/. Approval of the DD Form 2345 will be verified if proposal is chosen for award.

k. Certifications: In accordance with 13CFR Part 121, all small businesses selected for Phase I award must complete prescribed certifications at the time of award and prior to receipt of final payment.

Please access the Air Force SBIR/STTR site, https://www.afsbirsttr.com/Proposals/Default.aspx, for the certification template that must be completed, signed and submitted with the Phase I proposal. If selected for award the certification form required for submission prior to final payment may also be found at this site.

NOTE: Only Government employees and technical personnel from Federally Funded Research and Development Centers (FFRDCs) Mitre and Aerospace Corporations, working under contract to provide technical support to AF Electronic Systems and Space and Missiles Centers respectively, may evaluate proposals. All FFRDC employees have executed non-disclosure agreement (NDAs) as

a requirement of their contracts. Additionally, AF support contractors may be used to administratively or technically support the Government's SBIR Program execution. DFARS 252.227-7025, Limitations on the Use or Disclosure of Government-Furnished Information Marked with Restrictive Legends (Mar 2011), allows Government support contractors to do so without company-to-company NDAs only AFTER the support contractor notifies the SBIR firm of its access to the SBIR data AND the SBIR firm agrees in writing no NDA is necessary. If the SBIR firm does not agree, a company-to-company NDA is required. The attached "NDA Requirements Form" (page 9) must be completed, signed, and included in the Phase I proposal, indicating your firm's determination regarding company-to-company NDAs for access to SBIR data by AF support contractors. This form will not count against the 20-page limitation.

PHASE I PROPOSAL SUBMISSION CHECKLIST

Failure to meet any of the criteria will result in your proposal being **REJECTED** and the Air Force will not evaluate your proposal.

1) The Air Force Phase I proposal shall be a nine-month effort and the cost shall not exceed $150,000.

2) The Air Force will accept only those proposals submitted electronically via the DoD SBIR Web site (www.dodsbir.net/submission).

3) You must submit your Company Commercialization Report electronically via the DoD SBIR Web site (www.dodsbir.net/submission).

It is mandatory that the complete proposal submission -- DoD Proposal Cover Sheet, Technical Volume with any appendices, Cost Volume, Itemized Cost Volume Information, and the Company Commercialization Report -- be submitted electronically through the DoD SBIR Web site at http://www.dodsbir.net/submission. Each of these documents is to be submitted separately through the Web site. Your complete proposal **must** be submitted via the submissions site on or before the **6:00 am ET, 22 January 2014 deadline.** A hardcopy **will not** be accepted.

NOTE: If no exceptions are taken to an offeror's proposal, the Government may award a contract without discussions (except clarifications as described in FAR 15.306(a)). Therefore, the offeror's initial proposal should contain the offeror's best terms from a cost or price and technical standpoint. In addition, please review the model Phase I P.O. found at https://www.afsbirsttr.com/Proposals/Default.aspx and provide any exception to the clauses found therein with your cost proposal Full text for the clauses included in the P.O. may be found at http://farsite.hill.af.mil. **If selected for award, the award contract or P.O. document received by your firm may vary in format/content from the model P.O. reviewed. If there are questions regarding the award document, contact the Phase I Contracting Officer listed on the selection notification.** (See item g under the "Cost Volume" section, p. AF-4.) The Government reserves the right to conduct discussions if the Contracting Officer later determines them to be necessary.

The AF recommends that you complete your submission early, as computer traffic gets heavy near the solicitation closing and could slow down the system. **Do not wait until the last minute.** The AF will not be responsible for proposals being denied due to servers being "down" or inaccessible. Please assure that your e-mail address listed in your proposal is current and accurate. By late January, you will receive an e-mail serving as our acknowledgement that we have received your proposal. The AF is not responsible for notifying companies that change their mailing address, their e-mail address, or company official after proposal submission without proper notification to the AF.

AIR FORCE SBIR/STTR SITE

As a means of drawing greater attention to SBIR accomplishments, the AF has developed a SBIR/STTR site at http://www.afsbirsttr.com. Along with being an information resource concerning SBIR policies and procedures, the SBIR/STTR site is designed to help facilitate the Phase III transition process. To this end, the SBIR/STTR site contains SBIR/STTR Success Stories written by the Air Force and Phase II summary reports written and submitted by SBIR companies. Since summary reports are intended for public viewing via the Internet, they should not contain classified, sensitive, or proprietary information.

AIR FORCE PROPOSAL EVALUATIONS

The AF will utilize the Phase I proposal evaluation criteria in section 6.0 of the DoD solicitation in descending order of importance with technical merit being most important, followed by the qualifications of the principal investigator (and team), and followed by Commercialization Plan. The AF will utilize Phase II evaluation criteria in section 8.0 of the DoD solicitation; however, the order of importance will differ. The AF will evaluate proposals in descending order of importance with technical merit being most important, followed by the Commercialization Plan, and then qualifications of the principal investigator (and team). Please note that where technical evaluations are essentially equal in merit, and as cost and/or price is a substantial factor, cost to the Government will be considered in determining the successful offeror. The next tie-breaker on essentially equal proposals will be the inclusion of manufacturing technology considerations.

The proposer's record of commercializing its prior SBIR and STTR projects, as shown in its Company Commercialization Report, will be used as a portion of the Commercialization Plan evaluation. If the "Commercialization Achievement Index (CAI)", shown on the first page of the report, is at the 20th percentile or below, the proposer will receive no more than half of the evaluation points available under evaluation criterion (c) in Section 6 of the DoD 14.1 SBIR instructions. This information supersedes Paragraph 4, Section 5.4e, of the DoD 14.1 SBIR instructions.

A Company Commercialization Report showing the proposing firm has no prior Phase II awards will not affect the firm's ability to win an award. Such a firm's proposal will be evaluated for commercial potential based on its commercialization strategy.

On-Line Proposal Status and Debriefings

The AF has implemented on-line proposal status updates for small businesses submitting proposals against AF topics. At the close of the Phase I Solicitation – and following the submission of a Phase II via the DoD SBIR/STTR Submission Site (https://www.dodsbir.net/submission) – small business can track the progress of their proposal submission by logging into the Small Business Area of the AF SBIR/STTR site (http://www.afsbirstr.com). The Small Business Area (http://www.afsbirsttr.com/Firm/login.aspx) is password protected and firms can view their information only.

To receive a status update of a proposal submission, click the "Proposal Status" link at the top of the page in the Small Business Area (after logging in). A listing of proposal submissions to the AF within the last 12 months is displayed. Status update intervals are: Proposal Received, Evaluation Started, Evaluation Completed, Selection Started, and Selection Completed. A date will be displayed in the appropriate column indicating when this stage has been completed. If no date is present, the proposal submission has not completed this stage. Small businesses are encouraged to check this site often as it is updated in real-time and provides the most up-to-date information available for all proposal submissions**. Once the "Selection Completed" date is visible, it could still be a few weeks (or more) before you are contacted by the AF with a notification of selection or non-selection.** The AF receives thousands of proposals during each solicitation and the notification process requires specific steps to be completed prior to a Contracting Officer distributing this information to small business.

The Principal Investigator (PI) and Corporate Official (CO) indicated on the Proposal Cover Sheet will be notified by e-mail regarding proposal selection or non-selection. The e-mail will include a link to a secure Internet page containing specific selection/non-selection information. Small Businesses will receive a notification for each proposal submitted. Please read each notification carefully and note the Proposal Number and Topic Number referenced.

A debriefing may be received by written request. As is consistent with the DoD SBIR/STTR solicitation, the request must be received within 30 days after receipt of notification of non-selection. Written requests for debrief must be uploaded to the Small Business Area of the AF SBIR/STTR site (http://www.afsbirsttr.com). Requests for debrief should include the company name and the telephone number/e-mail address for a specific point of contract, as well as an alternate. Also include the topic number under which the proposal(s) was submitted, and the proposal number(s). Further instructions regarding debrief request preparation/submission will be provided within the Small Business Area of the AF SBIR/STTR site. Debrief requests received more than 30 days after receipt of notification of non-selection will be fulfilled at the Contracting Officers' discretion. Unsuccessful offerors are entitled to no more than one debriefing for each proposal.

IMPORTANT: Proposals submitted to the AF are received and evaluated by different offices within the Air Force and handled on a Topic-by-Topic basis. Each office operates within their own schedule for proposal evaluation and selection**. Updates and notification timeframes will vary by office and Topic. If your company is contacted regarding a proposal submission, it is not necessary to contact the AF to inquire about additional submissions.** Check the Small Business Area of the AF SBIR/STTR site for a current update. Additional notifications regarding your other submissions will be forthcoming.

We anticipate having all the proposals evaluated and our Phase I contract decisions within approximately three months of proposal receipt. **All questions concerning the status of a proposal, or debriefing, should be directed to the local awarding organization SBIR Program Manager.** Organizations and their Topic Numbers are listed later in this section (before the Air Force Topic descriptions).

PHASE II PROPOSAL SUBMISSIONS

Phase II is the demonstration of the technology that was found feasible in Phase I. Only Phase I awardees are eligible to submit a Phase II proposal. All Phase I awardees will be sent a notification with the Phase II proposal submittal date and a link to detailed Phase II proposal preparation instructions. If the contact information for technical/contracting points of contact has changed since submission of the Phase I proposal, contact the appropriate AF SBIR Program Manager, as found in the Phase I selection notification letter, for resolution. Please note that it is solely the responsibility of the Phase I awardee to contact this individual. Phase II efforts are typically two (2) years in duration with an initial value not to exceed $750,000.

NOTE: All Phase II awardees must have a Defense Contract Audit Agency (DCAA) approved accounting system. It is strongly urged that an approved accounting system be in place prior to the AF Phase II award timeframe. If you do not have a DCAA approved accounting system, this will delay / prevent Phase II contract award. If you have questions regarding this matter, please discuss with your Phase I Contracting Officer.

All proposals must be submitted electronically at www.dodsbir.net/submission. The complete proposal – Department of Defense (DoD) Cover Sheet, entire Technical Volume with appendices, Cost Volume and the Company Commercialization Report – must be submitted by the date indicated in the invitation. The Technical Volume is **limited to 50 pages** (unless a different number is specified in the invitation). The Commercialization Report, any advocacy letters, SBIR Environment Safety and Occupational Health (ESOH) Questionnaire, and Cost Volume Itemized Listing (a-i) will not count against the 50 page limitation and should be placed as the last pages of the Technical Volume file that is uploaded. (Note: Only one file can be uploaded to the DoD Submission Site. Ensure that this single file includes your complete Technical Volume and the additional Cost Volume information.) The preferred format for submission of proposals is Portable Document Format (.pdf). Graphics must be distinguishable in black and white. **Please virus-check your submissions**.

AIR FORCE PHASE II ENHANCEMENT PROGRAM

On active Phase II awards, the Air Force may request a Phase II enhancement application package from a limited number of Phase II awardees. In the Air Force program, the outside investment funding must be from a Government source, usually the Air Force or other military service. The selected enhancements will extend the existing Phase II contract awards for up to one year. The Air Force will provide matching SBIR funds, up to a maximum of $750,000, to non-SBIR Government funds. If requested to submit a Phase II enhancement application package, it must be submitted through the DoD Submission Web site at www.dodsbir.net/submission. Contact the local awarding organization SBIR Program Manager (see Air Force SBIR Organization Listing) for more information.

AIR FORCE SBIR PROGRAM MANAGEMENT IMPROVEMENTS

The AF reserves the right to modify the Phase II submission requirements. Should the requirements change, all Phase I awardees will be notified. The AF also reserves the right to change any administrative procedures at any time that will improve management of the AF SBIR Program.

AIR FORCE SUBMISSION OF FINAL REPORTS

All Final Reports will be submitted to the awarding AF organization in accordance with the Contract. Companies **will not** submit Final Reports directly to the Defense Technical Information Center (DTIC).

AIR FORCE
14.1 Small Business Innovation Research (SBIR)
Non-Disclosure Agreement (NDA) Requirements

DFARS 252.227-7018(b)(8), Rights in Noncommercial Technical Data and Computer Software – Small Business Innovation Research (SBIR) Program (May 2013), allows Government support contractors access to SBIR data without company-to-company NDAs only AFTER the support contractor notifies the SBIR firm of its access to the SBIR data AND the SBIR firm agrees in writing no NDA is necessary. If the SBIR firm does not agree, a company-to-company NDA is required.

"Covered Government support contractor" is defined in 252.227-7018(a)(6) as "a contractor under a contract, the primary purpose of which is *to furnish independent and impartial advice or technical assistance directly to the Government in support of the Government's management and oversight of a program or effort* (rather than to directly furnish an end item or service to accomplish a program or effort), provided that the contractor—

> (i) Is not affiliated with the prime contractor or a first-tier subcontractor on the program or effort, or with any direct competitor of such prime contractor or any such first-tier subcontractor in furnishing end items or services of the type developed or produced on the program or effort; and
>
> (ii) Receives access to the technical data or computer software for performance of a Government contract that contains the clause at 252.227-7025, Limitations on the Use or Disclosure of Government-Furnished Information Marked with Restrictive Legends."

USE OF SUPPORT CONTRACTORS:

Support contractors may be used to administratively process SBIR documentation or provide technical support related to SBIR contractual efforts to Government Program Offices.

Below, please provide your firm's determination regarding the requirement for company-to-company NDAs to enable access to SBIR documentation by Air Force support contractors. This agreement must be signed and included in your Phase I/II proposal package.

☐ Yes ☐ No Non-Disclosure Agreement Required (If Yes, include your firm's NDA requirements in your proposal.)

______________________________________ _____________________
Signer's Name/Position Date
Company

Air Force SBIR 14.1 Topic Index

AF141-062	Lightweight Electric Wires and Cables for Airborne Platforms and Battlefield Air Force Personnel
AF141-063	Modeling the Impact of Silica Particle Ingestion on Turbomachinery Life
AF141-064	Additive Metal Manufacturing (AMM) Process Development for Gas Turbine Engine Component Repair
AF141-065	Structural Health Monitoring (SHM) Methods for Aircraft Structural Integrity
AF141-066	Use more accurate aircraft usage data in predicting life and scheduling inspections
AF141-067	Structural Reliability Analysis
AF141-068	Generic Power/Propulsion Microcontroller for Unmanned Aircraft Systems (UAS)
AF141-070	Lithium-Ion (Li-ion) Battery Electrolytes using Nonflammable, Room-Temperature Ionic Liquids
AF141-071	Safe, Large-Format Lithium-Ion (Li-ion) Batteries for Aircraft
AF141-072	Fiber-Optic-Distributed Temperature Sensing System
AF141-073	Single-port Fiber-optic Probe for Imaging and Spectroscopy in Practical Combustion Systems
AF141-074	Developing Failure Stability in High-Reliability Sensor Design and Applications
AF141-075	Improved Design Package for Fracture Mechanics Analysis
AF141-076	Modular Flexible Weapons Integration
AF141-080	Air Cycle Toolsets for Aircraft Thermal Management System (TMS) Optimization
AF141-081	Launch Vehicle Systems Intended to Execute Suppressed Trajectories for Hypersonic Testing
AF141-082	Development of Approaches to Minimize Icing in Aircraft Heat Exchanger/Condenser Applications
AF141-083	Smart Aircraft Conceptual Design in Multidisplinary Design Optimization
AF141-084	Radiation Model Development for Combustion Systems
AF141-086	Lightweight Detachable Roll Control System
AF141-087	Additive manufacturing of Liquid Rocket Engine Components
AF141-088	Lowest Lifecycle Cost (LLC) Expendable Launch Vehicles
AF141-089	Electric Propulsion for Orbit Transfer
AF141-091	Physics-based modeling of solid rocket motor propellant
AF141-092	Advanced Integrity and Safety Assurance for Software
AF141-093	Development and Verification Tools/Processes for ASICs and FPGAs
AF141-094	Algorithm Based Error Estimation & Navigation Correction
AF141-096	Radiation Hardened Cache Memory
AF141-097	Next Generation Rad Hard Reduced Instruction Set Computer
AF141-099	Power Aware GPS User Equipment
AF141-100	Secure Time delivery Military GPS receivers in challenged RF environments using existing wireless infrasructure
AF141-101	Multi-Processor Array for Multi-Parametric Sensing in Cubesat DoD (or Air Force) Space Missions
AF141-102	M-code External Augmentation system
AF141-105	Algorithms for IR data
AF141-106	Innovative Technologies for Operationally Responsive Space
AF141-107	Improved AFSCN FCT Simulator
AF141-108	Forecasting of Solar Eruptions using Statistical Mechanics, Ensemble, and Bayesian Forecasting Methods
AF141-109	Adaptive antenna structures
AF141-110	Compact precision Atomic clock
AF141-111	GPS receiver cryptography key delivery leveraging NSA's Key Management Infrastructure (KMI)
AF141-113	Selective Availability Anti-Spoofing Module (SAASM) Compliant GPS Receiver for GEO
AF141-121	Satellite Threat Indications and Notification (TIN) in support of Space Situational Assessment
AF141-122	GPS PNT Flexible Satellite
AF141-123	Advanced Algorithms for Non-Resolved Space Based Space Sensing

AF141-124	Space-based RF Emitter Detection and Localization Using Field Programmable Gate Arrays
AF141-125	GaN Technology for GPS L-band Space Power Amplification
AF141-126	Optical System for Precision Atomic Clocks and Stable Oscillators
AF141-129	Mid-wave Infrared (MWIR) Illuminator for Ground and Small Unmanned Aircraft System (SUAS) Targeting
AF141-130	Miniature line-of-sight optical stabilization for hand-held laser marker/designator
AF141-131	Electromagnetic Radiation Effects on Weapons and Energetic Materials
AF141-132	Wide Field of View High Speed Strap Down Stellar Inertial Instrument
AF141-133	High Performance Angular Rate Sensors for Compact Inertial Guidance without GPS
AF141-134	Integrated Opto-Electronic Components for Multiaxis Inertial Measurement Units
AF141-135	High Performance Accelerometers for Precision Attack Weapons
AF141-136	Dual Mode Seeker/Sensor -LADAR/RF
AF141-137	Divert and Attitude Control System Technologies for Small Missile Applications
AF141-138	High Density Carriage Technology Innovation
AF141-139	MWIR Seeker-Sensor for Strap Down Weapon/SUAS applications
AF141-141	Weapons Effects FRMs for Contact or Embedded detonations in Fixed Targets
AF141-142	Plug and Play for Architecture for Modular Weapons
AF141-143	Data Analysis and Mining for Penetration Environment Dynamics (DAMPED)
AF141-144	Cooperative RF Sensors
AF141-145	Electromagnetic Effects in Energetic Materials
AF141-151	Engineered Process Materials for Casting of Aerospace Components
AF141-152	Uncertainty Quantification in Modeling and Measuring Components with Resonant Ultrasound Spectroscopy
AF141-153	ITO Repair on Transparencies
AF141-154	Conformal Conductivity Probe
AF141-156	Vibration Stress Relief
AF141-157	Galvanic Corrosion Prediction for Aircraft Structures
AF141-158	Durable, Low Friction Coating for Variable Speed Refueling Drogue (VSRD)
AF141-159	Portable Drill-Fastener
AF141-160	Abrasion Resistant Coating on Composite Substrates
AF141-161	Remotely Controlled Exhaust Coating Defect Mapping System
AF141-162	Methods to Enable Rapid Qualification of Additive Manufacturing Processes
AF141-163	Fabrication of aberration-free gradient index nonlinear optical materials
AF141-164	Programmable Accelerated Environmental Test System for Aerospace Materials
AF141-165	Standard Test Method for Prepreg Resin Impregnation Level
AF141-166	Aircraft Fastener Smart Wrench
AF141-167	Realistic Test Methods for Aircraft Outer Mold Line Treatment Materials
AF141-168	Chrome-Free Room Temperature Curing Fuel Tank Coating
AF141-169	Automated Surface Microstructure Nondestructive Evaluation (NDE) Process for Aerospace Materials
AF141-170	Efficient shaping or reshaping of complex 3D parts using engineered residual stress
AF141-172	Reliable and Large-Scale Processing of Organic Field Effect Transistors for Biosensing Applications
AF141-173	High Index of Refraction Materials for Printed Applications
AF141-174	Computational Tools to Virtually Explore Material's Opportunity Space from the Designer's Workstation
AF141-175	Advanced sub-scale component high temperature multi-axial test capability
AF141-177	Near Real-Time Processing Techniques for Generation of Integrated Data Products
AF141-178	Topographic/HSI Active Transceiver (TOPHAT)
AF141-179	Imaging Techniques for Passive Atmospheric Turbulence Compensation
AF141-180	FLIR/3D LADAR Shared Aperture Non-mechanical Beam Steering
AF141-181	Enhanced Compute Environment to Improve Autonomous System Mission Capabilities
AF141-182	Real Time, Long Focal Length Compact Multispectral Imager
AF141-183	Robust Hyperspectral Target Reacquisition Under Varying Illumination Conditions and Viewing Geometry

AF141-184	RF Photonic Multiple, Simultaneous RF Beamforming for Phased Array Sensors
AF141-185	Methodologies for Predicting Dormant Missile Reliabilities
AF141-186	Advance Tracking Algorithms to Meet Modern Threats
AF141-187	Increased Radio Frequency (RF) Sampling & Radar Architecture Upgrades
AF141-190	SATCOM Wideband Digital Channelized Receiver with Low-cost Silicon Technology
~~AF141-191~~	(This topic has been removed from the solicitation.)
AF141-192	Affordable E-band Radiation Hardened Mixed Mode Microelectronics
AF141-193	V-Band Traveling Wave Tube Amplifier with Extended Output Power
AF141-194	Noise Canceling Rad Hard Extremely High Frequency (EHF) Low Noise Amplifier
AF141-195	Characterization of Atmospheric Turbulence for Long Range Active Electro-Optic Sensors
AF141-196	Hybridization Techniques for Ultra-Small Pitch Focal Plane Arrays
AF141-197	Novel Signal Processing for Airborne Passive Synthetic Aperture Radar
AF141-198	Aperture Synthesis for Partially Coherent and Passive Illumination
AF141-199	Optical Isolator for Infrared (IR) Applications (2-15 micron)
AF141-203	Improved LHE Zn-Ni and Cd Plating Process
AF141-204	Improve Energy Source for NDI Equipment Tools
AF141-205	Non-Destructive Inspection for Medium Caliber Gun Barrel Fatigue Crack
AF141-206	Nonparametric Recurrent Event Data Analysis
AF141-207	Residual Stress Determination for Cold Expanded Holes
AF141-208	Material and Process Specification Optimization
AF141-209	Dimensional Evaluation of Aircraft Fuel Cells
AF141-210	Economic Alternative to Wc-Co HVOF Composition for ID Applications for Landing Gear
AF141-211	Enhanced Fuel Cells From Wastewater Treatment (Bacteria Generated System) as a Renewable Energy Source
AF141-212	Environmentally Friendly Stripping of Low Hydrogen Embrittlement (LHE) Chromium Plate
AF141-213	Method for Evaluating Candidates for Additive Manufacturing (AM) Processes
AF141-214	Beyond Fault Diagnosis and Failure Prognosis Fault Tolerant Control of Aerospace Systems
AF141-215	Corrosion- Preventative, Super-hydrophobic Coatings for Landing Gear
AF141-222	Hot Surface Ignition Apparatus for Aviation Fuels
AF141-223	Aircraft Wheel-Tire Dynamic Interface Pressure
AF141-224	Modeling Fuel Spurt from Impacts on Fuel Tanks
AF141-225	Advanced Infrared Emitter Array (AIREA)
AF141-226	Real Time Static and Dynamic Flight External Loads Analysis
AF141-227	Rule-Based XML Validation for T&E (RuBX)
AF141-228	Arc jet Test-Article Surface Recession Rate Monitor
AF141-229	Non-Intrusive, Seedless Global Velocimetry for Large Scale Hypersonic Wind Tunnels
AF141-230	Large Scale Combustion Air Heater Laser Ignition System
AF141-231	Alternative Approach to Contact Type Analogue Data Slipring
AF141-232	Temperature-Compensated Pressure Sensitive Paint (PSP) for use in Nitrogen Environments of Large-Scale Blowdown Hypersonic Facilities
~~AF141-239~~	(This topic has been removed from the solicitation.)
AF141-243	Advanced Space Antenna for GPS
AF141-244	Distributed Sensor Management for RSO Detection, Classification and Tracking
AF141-245	L-Band Wide Bandwidth High Performance Diplexer, Triplexer, and Quadruplexer
AF141-248	Improved satellite catalog processing for rapid object characterization
AF141-250	64MB+ Radiation-Hardened, Non-Volatile Memory for Space
AF141-251	On-Orbit Reprogrammable Digital Waveform Generator for GPS
AF141-252	Positioning, Navigating, Timing, Communications, Architecture, Mission Design
AF141-253	Disruptive Military Navigation Architectures

Air Force SBIR 14.1 Topic Descriptions

AF141-001 TITLE: Non-Silicon and Non-Boron based Leading Edges for Hypersonic Vehicles

KEY TECHNOLOGY AREA(S): Materials

OBJECTIVE: Identify and demonstrate a new material system with suitable material properties to realize the advanced leading edges for use in reusable or long flight time hypersonic vehicles.

DESCRIPTION: Air Force-relevant applications include but not limited to sharp leading edges, rocket nozzles, throats and engine combustion parts are key components that enable hypersonic flight. These leading edges and high temperature parts experience high temperatures over 2200°C at > Mach 8 flight conditions in high altitude air environment, resulting from aerothermally induced high heat flux. They further experience high ambient fluid velocities, mechanical vibrations, and thermal stresses from severe heat flux gradients and thermal shock. The materials that can survive such extreme conditions even for short exposure intervals are currently very limited. The state-of-the art high temperature fiber reinforced composites, including C/C, C/SiC and SiC/SiC composites, cannot meet the challenges. Ultra-High-Temperature Ceramics (UHTC) materials based on refractory metal diborides (HfB2 or ZrB2) and containing optimum silicon carbide concentration (in either bulk or CMC form) have demonstrated the best performances to date. However, these alloys are still not thermal shock resistant enough for reliable use in a cyclic environment. In addition, they suffer from accelerating oxidation and ablation above 1800°C due to volatilization of the glassy component. They also suffer tendency for spallation of the crystalline oxide partly due to phase transformations. The current UHTC technologies seem to have reached their limits, so new alloys are needed to address the property improvements required for the near future. Innovative material designs and possibly new fabrication technologies must be identified to enable applicability to advanced sharp leading edges for hypersonic vehicles. The next generations of ultra high temperature materials need to form high-density, stable crystalline oxide phases and they should not contain volatile phases. These materials will also need to have high thermal shock resistance (i.e., requiring high temperature strength of 100 Ksi, fracture toughness exceeding 7 MPam1/2 and thermal conductivity exceeding 50 w/m2K).

PHASE I: Identify candidate material systems and validate a proof-of-concept solution. Complete preliminary evaluation of the material performances with adequate laboratory evaluation approaches. This will require limited thermal-mechanical property evaluation from room temperature to at least 1600°C. Oxidation and thermal shock resistance should be assessed torch testing in air up to 2200°C.

PHASE II: Expand on Phase I results by further improvements to the material and its properties database using experiments that simulated condition of hypersonic flight. Identify and develop a cost-effective manufacturing process and produce the hardware designs for a four-inch long leading edge and provide a description for commercialization that takes into account civilian use for land-based power turbines, nuclear industry and nuclear medicine, and range of wide band gap electronic materials systems.

PHASE III DUAL USE APPLICATIONS: Transition the component technology to the Air Force system integrator or payload contractor, mature it for operational insertion, and demonstrate the technology in an operational level environment. Demonstration would include, but not be limited to, demonstration in a real system.

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KEYWORDS: ultra-high temperature materials, toughness, strength, thermal conductivity, leading edge, hypersonic, air breathing

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AF141-002 TITLE: Epitaxial Technologies for SiGeSn High Performance Optoelectronic Devices

KEY TECHNOLOGY AREA(S): Sensors

OBJECTIVE: Develop SiGeSn epitaxy on silicon and germanium substrates for new degrees of freedom in optoelectronic devices operating in the wavelength range between 2.0 and 5.0 micrometers.

DESCRIPTION: Conventional mid-infrared materials based on the III-V (GaInSb) and the II-VI (HgCdTe) materials are relatively expensive and incompatible with silicon-based integrated circuit processing. SiGe technology is pervasive for electronic applications, but the indirect energy gap prevents extensive applications in optoelectronics. Recent progress on SiGeSn (Silicon Germanium Tin) source materials and the promise of a direct energy gap for certain compositions promises significant optical performance, similar to the III-V compounds, but with compatibility with silicon circuit processing. In order to verify the expected materials parameters, and to make further breakthroughs, innovations are needed in growth, device and structure fabrication. SiGeSn emitters and detectors must be grown and characterized to determine their attributes and limitations.

One significant challenge involves the epitaxy of high quality layers on silicon and germanium substrates, depending on application. Compared to conventional SiGe epitaxy, the main limitation comes from the need to modify the growth conditions, such as reducing the substrate temperature. Novel CVD materials are required such as deuterated stannane as the Sn source. The optimum growth parameters are solicited to produce device-grade material.

Once high quality epitaxy is available, it is important to find how device performance depends on material properties. With the compositional dependence of lattice constant and band gap, the optimum layer structures, and heterostructure and superlattice combinations are sought. Interesting devices based on strained layer superlattices and quantum cascade mechanisms can be designed and fabricated. While SiGe and III-V optoelectronic devices have been well characterized in terms of band offsets, optical confinement, and radiative recombination, little is known about these effects in SiGeSn. Innovative ideas leading to effective SiGeSn optoelectronic devices are solicited.

PHASE I: Demonstrate the feasibility to fabricate optoelectronic devices by the growth of epitaxial SiGeSn films on Si or Ge substrates either by MBE (Molecular Beam Epitaxy) or CVD (chemical vapor deposition) methods. Provide experimental evidence for a direct energy gap and significant optoelectronic performance, including high optical absorption and efficient infrared emission.

PHASE II: Fabricate and characterize infrared emitters and detectors operating within the spectral range of 2 - 5 um. Demonstrate significant performance through enhanced and longer wave performance compared to other Group-IV detectors, and by efficient light emission comparable to that of Group-III-V materials.

PHASE III DUAL USE APPLICATIONS: The device quality SiGeSn films will be used to make infrared device structures as required by military and commercial customers including those who manufacture integrated circuits and IR optical emitters and detectors.

REFERENCES:
1. R. Soref, J. Kouvetakis, and J. Menendez, “Advances in SiGeSn/Ge Technology,” Materials Research Society

Symp. Proc., v. 958, 0958-L01-08, 2007.

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KEYWORDS: SiGeSn, SiSn, GeSn, silicon, germanium, silicon-germanium-tin, Molecular Beam Epitaxy, MBE, CVD, chemical vapor deposition, emitters, detectors, Group IV photonics, silicon photonics, optoelectronic devices, device fabrication, growth, heterostructures, radiative recombination, quantum efficiency, semiconductor characterization, superlattices, infrared

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AF141-003 TITLE: Variable Precision Filters

KEY TECHNOLOGY AREA(S): Sensors

OBJECTIVE: The development of innovative mathematical techniques for the design of digital filters allowing trade-offs between accuracy, precision and memory.

DESCRIPTION: The design of finite impulse response (FIR or non-recursive) and infinite impulse response (IIR or recursive) digital filters has a long history and, over the years, many methods have been developed to design FIR, IIR filters, adaptive filters and filter cascades. The primary task of a digital filter is to alter in some prescribed manner the frequency content of a signal. In most cases, the prescribed frequency modifications cannot be achieved exactly and, hence, filter design problems involve some type of approximation or optimization. This optimization is typically a balance between simultaneously matching the magnitude response of the filter, the phase response of the filter or the group delay of the filter with the prescribed filter specifications. These challenging optimization problems are then solved using a variety of algorithms. A critical property of a filter is its application cost, especially in problems with stringent execution time and hardware constraints. Widely used techniques for filter design define optimality of design differently and may not directly reflect the cost of filter application. For example, an algorithm that produces an optimal equaripple FIR design may not yield the most efficient (cost effective) filter for achieving given specifications. In particular, it is difficult to obtain an accurate, robust and highly efficient design for a filter that requires sharp transitions within narrow sub-bands or requires a complicated structure of the pass-band. In hardware implementations, optimization at algorithm level typically achieves greater cost reduction than at architecture or logic level. If the filter design specifications are generated via a measurement process, instead of a fixed set of specifications, one would like a design algorithm that guarantees convergence and assures accuracy and efficiency of the resulting filter. This ability to automatically design in real time such filters based on measured data could significantly impact many applications. Desirable approaches will allow real-time, near optimal filter re-design that is then automatically deployed. The approach should lend itself to efficient hardware implementations on a variety of architectures. Because the design of optimized filters may require significant expert knowledge there is interest in new, robust approaches to automate filter design and make it possible for their use in real time applications.

PHASE I: A clear description of the mathematical framework for the filter design and a demonstration of the feasibility of the proposed approach. Also the approach must be shown to perform the same or better than expert-guided techniques. In particular it must be demonstrated on filters with sharp transitions within a very narrow bandwidth as well as filters with a complicated structure of the passband.

PHASE II: Successful completion of Phase II should provide a user-friendly software implementation of the proposed solutions within one or more application domains.

PHASE III DUAL USE APPLICATIONS: Reduced power and weight for diverse military and civilian applications including communications and radar.

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KEYWORDS: Optimal Filter Design, IIR filters, FIR filters

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AF141-004 TITLE: Radio-frequency Micro-electromechanical Systems with Integrated Intelligent Control

KEY TECHNOLOGY AREA(S): Sensors

OBJECTIVE: Improve the robustness and reliability of radio-frequency micro-electromechanical systems by orders of magnitude beyond the state of the art, making them suitable for defense applications.

DESCRIPTION: Radio-frequency micro-electromechanical systems (RF MEMS) have many performance advantages as microwave switches, tuners, filters and phase shifters with higher linearity, lower loss and lower power consumption than what are currently achievable by ferrite and semiconductor alternatives [1]. These advantages make RF MEMS attractive for radar and communication applications, especially those involving reconfigurable RF front ends. However, defense applications of RF MEMS have so far been hindered by yield, robustness and reliability issues [2]. Recently, commercial applications of RF MEMS, such as in antenna tuners for mobile handsets, have started to take off [3]. For high-yield, high-volume and low-cost fabrication, these commercially available RF MEMS are typically fabricated by using the same complimentary metal-oxide semiconductor (CMOS) technology as in the fabrication of most integrated circuits [3]. Therefore, it is desirable to take advantage of intelligent control achievable by using CMOS integrated circuits to improve the robustness and reliability of RF MEMS by orders of magnitudes, making them suitable for defense applications, as well as demanding commercial applications such as in cellular base stations [4]. Giving the interest and advance in the private sector in this topic, use of government materials, equipment, data or facilities is not anticipated.

PHASE I: Research the actuation mechanism and performance characteristics of RF MEMS switches and develop the best intelligent closed-loop feedback control strategy to improve their robustness and reliability. Design an intelligent control circuit that can allow RF MEMS switches to operate over the military temperature range with long operating life. Evaluate potential improvement through simulation.

PHASE II: Fabricate the control circuit and integrate it with RF MEMS switches to demonstrate reliable operations with 1) -55 °C to 125 °C ambient temperature variation, 2) week-long continuous contact, and 3) 100 billion repetitions of intermittent contact, respectively. Evaluate the trade-off between performance, robustness, reliability, cost, size and power consumption.

PHASE III DUAL USE APPLICATIONS: Robust and reliable RF MEMS switches, tuners, filters and phase shifters in reconfigurable RF front ends for defense radar and communication systems, as well as cellular base stations.

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1. G. M. Rebeiz, RF MEMS Theory, Design Technology. Hoboken, NJ: Wiley 2003.

2. J. C. M. Hwang, and C. L. Goldsmith, "Reliability of MEMS capacitive switches," in IEEE MTT-S Int. Wireless Symp. Dig., Apr. 2013.

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KEYWORDS: radio frequency, microwave, micro-electromechanical system, switch, tuner, filter, phase shifter, robustness, reliability

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AF141-005 TITLE: SMART Bandage for Monitoring Wound Perfusion

KEY TECHNOLOGY AREA(S): Biomedical

OBJECTIVE: Develop and demonstrate an innovative wound dressing that quantitatively reports tissue perfusion for monitoring and optimizing wound healing.

DESCRIPTION: The current standard-of-care for wounds and grafts relies on subjective observations of tissue health that are episodic and can vary greatly between caregivers with different degrees of training (1). For example, measurements of tissue perfusion, a critical parameter necessary for wound and graft healing, currently rely on qualitative assessments of wound healing, including tissue color, temperature, capillary refill and smell. This lack of quantitative tissue oxygenation information can lead to poor outcomes; without accurate knowledge of tissue perfusion, thermal burn sites, for example, may be inadequately debrided, leading to subsequent graft failure with accompanying aesthetic and functional consequences (2). This lack of operator-independent, quantitative and non-episodic perfusion monitoring of wounds, grafts and flaps (3) has been recognized as a major unmet need for our wounded warriors. Current oxygen sensing tools rely on fragile probes that require extensive training to use correctly, provide only point measurements, and are not easily integrated into battlefield or surgical settings. Problematically, current wound assessment and therapeutic methods require the removal of dressings, resulting in further disruptions to the surgical site or wound bed that can lead to discomfort, compromised healing and complications. New objective approaches for monitoring and treating wounds are needed to improve surgical outcome and wound healing for both military personnel and civilians.

To address these needs, a transparent wound dressing will be developed that provides real-time maps of tissue oxygenation and other parameters across entire wounds, surgical beds or burn sites for direct, continuous monitoring of tissue health throughout the healing process. A potential approach to this development is to build upon the research described in reference (4). A further development aim of this topic, to eliminate the need for dressing removal during treatment, is a therapeutic release system integrated into the bandage for interactive, spatio-specific delivery of drugs directly to vulnerable tissues. This Sensing, Monitoring, And Release of Therapeutics (SMART) bandage system could then be used for post-treatment wound monitoring to provide caregivers with a continuous, quantitative read-out of treatment response and wound healing.

PHASE I: Develop, refine and demonstrate an oxygen sensing bandage that incorporates an oxygen sensing layer removed from direct tissue contact, and a semi-permeable barrier layer that buffers the sensing layer from room oxygen.

PHASE II: Based on Phase I results, develop and test a clinical prototype system consisting of the oxygen sensing bandage, an optical imaging device, and software algorithms that will integrate the two and enable quantitative mapping of wound-healing parameters. Also in this phase, create the initial design specifications for prototyping the therapeutic release capability within the bandage.

PHASE III DUAL USE APPLICATIONS: The focus in Phase III will be to conduct human studies of a fully integrated oxygen sensing and monitoring system in both battlefield and civilian settings, and to integrate the prototype therapeutic release capability into the bandage system.

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KEYWORDS: wound healing, wound dressing, bandage, oxygen, perfusion, grafts, transplants, burns

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AF141-006 TITLE: Shockwave Consolidation of Materials

KEY TECHNOLOGY AREA(S): Materials

OBJECTIVE: To develop materials that are far from thermodynamic equilibrium domain (highly doped polycrystalline materials, nano-structured systems and supersaturated structures, etc.). The processing includes shockwave consolidation and external fields.

DESCRIPTION: Conventional processing techniques typically prepare materials from a melt or using powder metallurgy techniques, such as hot pressing followed by sintering. These conventional techniques enable production of materials close to the equilibrium state with relatively large grains (crystallites) within the material and cause the loss of nanostructure dimensionality. Materials design and processing approaches at or close to the equilibrium state can impose limitations on the properties.

Processing utilizing shockwave consolidation via explosions, high pressure gun systems, and/or electromagnetic waves (e.g., microwaves, electron beams, laser, etc.) may lead to new materials with desirable, tailorable properties. A specific thrust area of interest is the discovery of new techniques for consolidation of nano powders, measuring, and analyzing thermal phenomena induced by shock waves and under aforementioned external fields during processing. This requires understanding of the time domain and associated definition for the state of the material in relation to equilibrium state.

The ultimate goal of exploiting these phenomena is to stabilize non-equilibrium phases and design future materials and components that break the paradigm of today's materials where the boundaries of performance/failure are defined by the equilibrium state. The end-use areas could include, but are not limited to, transparent laser materials, multifunctional ceramics, shape memory alloys and reactive materials.

PHASE I:
1. Define and design shockwave-driven processing techniques.

2. Demonstrate hierarchical stability of the microstructure as function of external stimuli, e.g., explosive compaction, high speed gas guns, or electromagnetic waves.

3. Design proof-of-concept material in non-equilibrium state by demonstrating supersaturated dopant concentration (at least 10x of equilibrium dopant concentration).

PHASE II:
1. Further improvements to material system and its properties.

2. Establish quantitative "Selection Rules" for stability of heterogeneous structures. Map out the non-equilibrium "phase diagram" enabled through shockwave processing.

3. Understand processing trade space by correlating time and length scales with emerging microstructure.

4. Identify and develop a cost-effective manufacturing technique to achieve non-equilibrium materials developed in Phases I and II.

PHASE III DUAL USE APPLICATIONS: Continue development of the various aspects of shockwave consolidated materials to enable accomplishment of the Phase II objectives and deliverables. Transition the component technology to a DoD system integrator, mature it for operational insertion, and validation.

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KEYWORDS: shockwave, non-equilibrium, explosive, high, power, sintering, shock consolidation, non-equilibrium material, nano-powder, electromagnetic

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AF141-009 TITLE: Single Photon Sources for Free Space Quantum Key Distribution Systems

KEY TECHNOLOGY AREA(S): Electronics

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop and demonstrate an on demand single photon source for use in a free-space Quantum Key Distribution (QKD) satellite to ground configuration.

DESCRIPTION: Security in quantum key distribution (QKD) arises from the principle that the quantum state of a single photon, prepared in an unknown basis, can only be determined with a probabilistic outcome. This fact both limits the information that may be gleaned by an eavesdropper and allows eavesdropping to be detected via errors that are introduced into the quantum channel.

In practice, attenuated laser pulses are often employed as a photon source and offer a wide range of useful spectral and temporal characteristics. However, the photon number of such pulses is described by Poissonian statistics and necessarily includes multi-photon pulses. The pulses that contain multi-photons can in principle be exploited by an eavesdropper to gain information without detection.

Recent developments in non-Poissonian photon sources suggest that it may be possible to minimize or eliminate the risk of multi-photon pulses for use in QKD. In order to be useful in a free-space QKD scenario that includes atmospheric propagation, a non-Poissonian source would need to be developed with the following characteristics:

1. The 2nd order coherence function, g(2), should approach zero.
2. The center wavelength should lie within an atmospheric transmission band and within a region of high detector quantum efficiency.
3. The spectral emission width should be of the order of 1 GHz.
4. The controlled emission timing jitter should be less than 100 picoseconds.
5. The temporal emission width should be less than 1 nanosecond.
6. The emission rate should be greater than 1 MHz.
7. The source should be directional with near-diffraction-limited wavefront quality.

Desirable sources will be controllable and emit a single photon “on demand” at an arbitrary user-specified time with very low probability of zero or multi-photon emission. Sources will produce narrowband single photon emission in the spectral range of 750 – 1600 nm at a rate of = 1MHz or higher. The source should be compatible with free space propagation in the Earth’s atmosphere (space-to-ground links) and compatible with corresponding developments with single photon detector technologies. The use of narrowband emission allows for spectral filtering for daytime use. To be most effective this source should show a high contrast in antibunching (single photon emission), exhibit high quantum efficiency, show extreme photostability (photoluminescence stability (i.e., no photobleaching) and/or extreme electrostability (electroluminescence stability). To be extensively used, this source should be robust and capable of packing for airborne or space platforms.

PHASE I: Design an on-demand single photon source capable of producing: narrowband photon emission in the spectral range 750-1600nm; single photons at a rate of = 1 MHz. Approach should include a detailed design description & supporting physics based analysis to demonstrate achievement of sub-Poissonian statistics. Prepare a plan for prototype development & testing & determine DoD application feasibility.

PHASE II: Prepare and test prototype single photon source with high emission rates, high contrast antibunching and efficiency, photostability and electrostability. Demonstrate achievement of sub-Poissonian statistics by intensity autocorrelation measurements of g(2). Identify packaging and systems integration issues for operation in a LEO environment.

PHASE III DUAL USE APPLICATIONS:
Military: Encryption technologies are needed for all DoD & NRO spacecraft & many other operational systems. Commercial satellites and ground system will benefit in the same manner as military spacecraft from this technology. Future quantum communications systems will also be derived from this research.

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KEYWORDS: Single photon source, free space, laser communication, quantum key distribution, sub-Poissonian

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AF141-011 This topic has been removed from the solicitation.

AF141-012 TITLE: Rapid Mission Planning for Desirable Viewing Conditions

KEY TECHNOLOGY AREA(S): Space platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: To develop a method to optimize scheduling and planning for Space Situational Awareness (SSA) collects.

DESCRIPTION: The AFSPC (Air Force Space Command) Space Surveillance Network (SSN) and AFRL (Air Force Research Laboratory) utilizes a number of ground based observatory telescope systems to observe satellites and obtain awareness to support Space Situational Awareness (SSA). These telescope systems can operate in a variety of configurations to collect highly resolved images of Low Earth Orbiting (LEO) satellites and to perform non-resolved detection/astronomy/photometry of both Geosynchronous Earth Orbit (GEO) and LEO satellites. In astronomy, mission planning and scheduling of telescopes is simply a matter of determining whether the object is within the field of regard of the sensor, and is bright enough to be seen by the sensor. Since the brightness usually doesn't vary, and the line of sight between the object and the sensor can be predicted with great accuracy years in advance, the scheduling is pretty straightforward, other than the variable of weather. However, for satellites, the brightness is highly dependent on the orientation of the satellite and the solar phase angle—the angle between the sun-satellite-sensor. Furthermore, our knowledge of the orbit is not precise enough for us to predict months in advance what the optimal viewing opportunities will be. Current processes are manpower intensive and mostly based on whether the satellite breaks the horizon, and an average brightness that doesn't account for phase angle. Collecting data under sub-optimal conditions can lead to data that is useless, thus wasting resources that could be devoted elsewhere.

AFRL has previously developed detailed models that accurately predict the appearance of a satellite under a variety of illumination conditions. Furthermore, validated models of noise caused by atmospheric turbulence and scattering are prevalent within the academic community. AFRL is seeking an automated methodology to use an understanding of satellite radiometry, site-specific parameters, satellite orbital uncertainties and atmospheric turbulence and scattering to improve our ability to plan observation schedules and improve efficiency.

While model-based predictions are often a good predictor of brightness, sometimes models are wrong or are unavailable. The system can have access to a historical database of observations including object number, day/time, and calibrated magnitude, enabling the ability to choose optimum viewing conditions based on actual data, rather than based on models. Automated methods are preferred over manual methods.

PHASE I: Develop a logic tree of factors for mission planning. Assess existing databases, radiometric, atmospheric, noise models and performance data against the logic tree. Formulate an automated method that provides a 6-month schedule, a refined monthly schedule and a detailed weekly schedule to optimize collection opportunities for a variety of sensor systems and runs within 2 minutes.

PHASE II: Implement an improved mission planning tool that permits AFSPC and AFRL SSA assets to improve collection efficiency and success. Develop an automated method for mission planning that provides a 6-month schedule, a refined monthly schedule and a detailed weekly schedule to optimize collection opportunities. Demonstrate the mission planning tool using AFRL telescopes at the Maui Space Surveillance and Starfire Optical Range sites.

PHASE III DUAL USE APPLICATIONS: Worldwide deployment to AFSPC and AFRL SSA assets.

REFERENCES:
1. Hussein, I.I.; DeMars, K.J.; Fruh, C.; Erwin, R.S.; Jah, M.K., "An AEGIS-FISST integrated detection and tracking approach to Space Situational Awareness," Information Fusion (FUSION), 2012 15th International Conference on , vol., no., pp.2065,2072, 9-12 July 2012.

2. Linares, R., Jah, M., Crassidis, J., Leve, F., Kelecy, T., (2012). Astrometric and Photometric Data Fusion for Inactive Space Object Feature Estimation, Journal of the International Academy of Astronautics: Acta Astronautica, Accepted (08/01/12).

3. DeMars, K., Hussein, I., Jah, M., Erwin, R.S., (2012). The Cauchy-Schwarz Divergence for Assessing Situational Information Gain, 15th International Conference on Information Fusion, Singapore, Singapore, July 9 – July 14.

KEYWORDS: mission planning, space situational awareness, satellite modeling

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AF141-013 TITLE: Efficient Photometry

TECHNOLOGY AREA(S): Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Decrease the time burden of photometric collection using stars serendipitously collected with optical sensors without compromising calibration accuracy and data quality.

DESCRIPTION: Photometric data collection techniques have become key for space surveillance. Photometric techniques can be used on most existing electro-optical sensors and have become a routine collection method. Photometric data contributes to space object identification and characterization techniques and are being utilized more than ever.

However, current photometric methods are cumbersome, requiring 10-12 stars' calibrations to be collected in addition to the photometric collection of interest. The potential exists to reduce collection time 90% by eliminating this calibration time. Additionally, some data collected cannot be used, because star calibrations were not performed at the time of collection. This has the potential to significantly increase the capacity of operational sensors.

New methods of photometric calibration are required that can take any image file, extract stars and any other objects in the field, and precisely (<10% photometric magnitude error) calibrate photometric curves for Maui Space Surveillance Site data types. The new technique should include corrections for star color terms as well as corrections for gain and bias errors. Stellar calibration by astronomers around the world has produced extensive catalogs of calibrated stars. In frame photometric calibration is possible. Current methods perform in frame photometry collected on sensors with a large field of view (FOV) and on objects with a relatively similar velocity relative to the stars. State-of-the-art advancements will provide photometric calibration for data collected on sensors with a 20 arcmin or smaller FOV, and preferably sensors down to a 6 arcsec FOV. Techniques should be applicable at all orbital regimes. Alternatively, new methods of photometric calibration using GPS have been identified. Either technique could be potentially used to make photometry collection more efficient.

The best solutions will be low cost, globally applicable, will apply to many sensors and wavelengths, will operate in near real time, and will take no additional collection time. Proposals should identify the expected performance including: calibration accuracy, the sensor FOVs it applies to, the signal to noise ration (SNR) required and any additional benefits the processing technique may have. Include examples of demonstrated experience with photometric, astrometric collections and analysis, experience analyzing imagery, and related software development in the proposal.

PHASE I: Assess solutions and design prototype software. Update performance analysis. Include past examples of designing similar software in proposal.

PHASE II: Using techniques identified in Phase I, further develop and mature the research code into a standalone software module that is easily integrateable into existing data pipeline. Test and evaluate the software to confirm performance predictions and robustness with different with data collected at Maui Space Surveillance Site.

PHASE III DUAL USE APPLICATIONS: Software will be of use to government and astronomical entities. This product can reduce collection time by 90% and save significant dollars by automating photometric calibration to operate in real time and eliminate the manpower required to reduce data that is later discovered unusable.

REFERENCES:

1. "Space situational awareness applications of the PS1 AP catalog," Monet, D. AMOS Conference Proceedings, p 40 (2006).

2. "Measuring NIR Atmospheric Extinction Using a Global Positioning System Receiver," Blake, C., Shaw, M., Publications of the Astronomical Society of the Pacific, Vol. 123, No. 909 (November 2011), pp. 1302-1312.

KEYWORDS: photometry, astrometry, calibration, astronomy

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AF141-014 TITLE: Decision Aid to Threat Identification and Intent Modeling

KEY TECHNOLOGY AREA(S): Space platform

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OBJECTIVE: Develop a method to monitor satellite observables using optical and other data sources to predict, and understand, future activities of operational satellites in orbit.

DESCRIPTION: Determine future space activities by data mining to link disparate data together to determine patterns and trends that may be indicators of future events that might threaten our satellites. To accomplish this, determine if available data and models of human behavior are sufficient to provide a probabilistic prediction of what deviations in the data might indicate. The goal would be to develop an understanding of what observables are vailable to establish a baseline of normal space operations, what deviations are significant and how this data can be used to develop a decision aid to identify and confirm with high confidence that operations have deviated from normal behavior. It requires an assessment of what types of information may be available to feed the model, whether the information can be collected with sufficient accuracy or timeliness and whether the data can be processed quickly enough to be meaningful. Please include any requested data sources needed to accomplish the research in the proposal. Include references in proposals on how similar approaches to the proposed technique have been validated, particularly if they have been validated by the government. State-of-the-art advancements will identify potential threats several hours prior to threat event occurrence.

Proposals should detail the experience in information theory, or behavior modeling and experience in validating theoretical approaches similar to the one proposed. Proposals should also include what existing data sources would be utilized. If needed, DoD High-Performance Computing resources would be available to support this research and development.

PHASE I: The initial step will be to develop a logic tree of factors that can be measured and or observed that might affect standard operations of a satellite control network. The next step would be to identify potential approaches to aggregating the individual observables into a model that might be used to assess operating modes and deviations thereto.

PHASE II: Develop a model or decision aid used to interpret data sources identified in Phase I. Predict potential future satellite operations, both near term and long term if possible. Quantification and probability of generating false positives (a deviation identified when none exists) vs. false negatives (a deviation not identified) will be assessed. Measure performance against notional scenarios and timelines.

PHASE III DUAL USE APPLICATIONS: Decision aids and threat identification; modeling of intent.

REFERENCES:
1. Hussein, I.I.; DeMars, K.J.; Fruh, C.; Erwin, R.S.; Jah, M.K., "An AEGIS-FISST integrated detection and tracking approach to Space Situational Awareness," Information Fusion (FUSION), 2012 15th International Conference on, pp. 2065,2072, 9-12 July 2012.

2. Linares, R., Jah, M., Crassidis, J., Leve, F., Kelecy, T., (2012). Astrometric and Photometric Data Fusion for Inactive Space Object Feature Estimation, Journal of the International Academy of Astronautics: Acta Astronautica, Accepted (08/01/12).

3. DeMars, K., Hussein, I., Jah, M., Erwin, R.S., (2012). The Cauchy-Schwarz Divergence for Assessing Situational Information Gain, 15th International Conference on Information Fusion, Singapore, Singapore, July 9 – July 14.

KEYWORDS: modeling, threat identification, space situational awareness, data fusion

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AF141-015 TITLE: Strategic Collection for Rapid Return to Continuous Monitoring for Deep Space Wide Area Search and Tasked Sensors

KEY TECHNOLOGY AREA(S): Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop collection CONOPs and software prioritized at GEO (extending as possible to other regimes) using optical telescopes to maintain custody of objects, and detect and revisit new objects that enter the space.

DESCRIPTION: The potential exists to maintain consistent awareness of all man-made objects extending to Geosynchronous Earth Orbits (GEOs) and super-synchronous regimes by combining the use of multiple telescopes: one tasked to observe known or newly discovered objects (uncorrelated targets or UCTs), and one repeatedly surveying the sky to detect changes and discover new objects. Scheduling these sensors is not straight forward as they have limitations on sensitivity, field of view, required revisit time, operation in inclement weather, and maintenance downtime. Solutions are needed that can maximize awareness of man-made objects over a region by building a scheduler that adapts to real-time operational status changes and is robust enough to follow up on UCTs and meet high priority satellite needs. Scheduling strategies to optimize search patterns for 2 or more telescopes need to be developed so that they can operate in "search mode" where most appropriate and efficient and look for specific objects in a "tasked mode" mode when most efficient. Solutions need to maximize the coverage area and minimize the number of lost objects, providing a complete picture of objects overhead. State-of-the-art solutions will detect and correlate 90% of all objects above the sensors' threshold sensitivity within the sensors' field of regard within 8 hours of continuous sensor ready status.

Examine potential solutions in Phase I. Establish a simulation to quantify the information and performance gains that can be achieved by candidate mission planning and tasking methods. The simulation should consider existing sensors of varying field of view, sensitivity, and search rate capability but may include other sensors as well. Consider varying the scan rates, integration times and operating in a search mode or tasked mode to maximize coverage area, repeat observations, object velocities handled, to maintain custody of all man-made objects on orbit, detect changes, detect new dim objects, and follow up/correlate/determine orbits/and characterize new dim objects. Quantify the probability of follow-up detection. In the proposal, detail your simulation capability and how it has been validated. Techniques will be demonstrated at the Maui Space Surveillance Site (MSSS). Revisit rates and duration of collections for tasked objects and MSSS sensor specifics available at award.

For the software development in Phase II:

1. Build real-time mission planning software for scheduling search-based in concert with tasked sensors to reduce the number of UCTs near GEO orbits. Include a user interface that accepts input on weather, sensor outages, and is modular enough to incorporate advanced processing algorithms to determine search rate. Software development must be modular to accept future improvements in the processing algorithm without significant code rewrite. It will start with a nominal sensitivity and coverage rate search sensor but can be configured for operational desires (increase repeat frequency, increase coverage area, increase range of velocities, etc.) and based on the analysis accomplished in Phase I.

2. Build real-time mission planning software for collection with tasked sensors to maximize coverage area/sensitivity/revisit/number of objects near GEO. Accounting for weather and sensor outages, collect frequently enough to maintain custody, detect changes, and detect new dim objects, and follow up/correlate/determine orbits/and characterize new dim objects. Software development must be modular to complement future improvements in this area. It should be able to be initially configured by the sensor parameters and operational tasking (increase repeat frequency, increase tasked list, wider FOV sensor, increase range of velocities, etc.).

PHASE I: Accomplish the simulation. Identify scheduling and tasking strategies for efficiently maintaining custody, detecting changes and new dim objects, and follow up/correlate/determine orbits/and characterize cued and uncued targets. Simulate candidate techniques and quantify the likelihood of follow-up detection. Document parameters used and results in final report.

PHASE II: Accomplish software development. Using techniques analyzed in Phase I, further develop and mature the research code into a standalone software module that is easily integrateable with other systems. Integrate and test software at Maui Space Surveillance Site.

PHASE III DUAL USE APPLICATIONS: Military Application: Software to support the Joint Space Operations Center (JSPOC). Commercial Application: Similar support to government/commercial space.

REFERENCES:

1. “Sensor-scheduling simulation of disparate sensors for space Situational Awareness,” Hobson, T.A., Clarkson, I.V.L., AMOS Conference Proceedings (2011).

2. “Covariance-Based Network Tasking of Optical Sensors,” Hill, K., Sydney, P. Hamada, K. Cortez, R., Luu, K., Jah, M., Schumacher, P.W., Coulman, M., Houchard, J., Naho’olewa, D. Proc. AAS/AIAA Space Flight Mechanics Meeting (February 2010).

3. “Covariance analysis for deep-space satellites with radar and optical tracking data,” Miller, J.G., AAS 05-314, AAS/AIAA Astrodynamics Specialists Conference, Lake Tahoe, CA (August 2005).

KEYWORDS: tasking, space surveillance, search, tasked, catalog maintenance, threat detection, persistent tactical monitoring

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AF141-016 TITLE: Persistent Wide Field Space Surveillance

KEY TECHNOLOGY AREA(S): Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: To develop and demonstrate innovative, scalable approach to space object detection that permits the detection of dim orbiting objects using a very wide field of view, non-articulated sensor system architecture.

DESCRIPTION: Conceive an approach to this challenging field of dim object detection/wide field of view (FOV) surveillance that exploits recent developments in sensors and data processing/manipulation. Preliminary mathematical models of the proposed techniques indicate significant performance improvements. Trades studies will highlight the cost for various FOV’s and system detection and track formation sensitivity. Special consideration to systems that eliminate the need to mechanically point and track, are highly scalable in the following areas: increase the system’s limiting magnitude for detection and track formation (detect smaller and dimmer objects) and increase the area searched in a given time. Systems that exploit the rapidly growing “off-the-shelf” technology of data bus architectures, networking and electro-optic sensors may be especially attractive to allow for affordably realizable systems. State-of-the-art improvements will cover greater than 1000 square degrees per hour and see at least 18th visual magnitude and operates at AFRL’s Starfire Optical Range (SOR) to observe GEO or deep space object above 45 degrees elevation conditions during typical sky conditions. The system should be designed with a cost goal less than $1 million for building a single system and can be easily installed at SOR.

Start by providing a mathematical model of the system design. In-depth examination of technology-related assumptions will be performed and validated. Develop simulation tools based on these existing mathematical models that will provide performance predictions for various candidate sub-configurations. These simulation tools will predict performance for a large range of object optical cross sections in a given search pattern, and site "seeing" conditions in order to demonstrate the candidate system's range of performance.

Perform small-scale laboratory tests of the concept to demonstrate key required architecture capabilities--the ability to acquire, process, store and manipulate data. Laboratory testing will be followed by actual field testing of a small-scale system architecture. Field experiments will be structured to obtain data to validate the system architecture simulation/model.

Outlining the proposed design and performance, impacts to nominal operations, scalability and estimated cost and implementation schedule for this Phase I work plan. Provide monthly reviews.

Utilizing data obtained during Phase I to further refine models/simulation tools of the system concept. Additional simulation studies will be performed to refine performance predictions for the candidate system. The Phase I small-scale system architecture will be enlarged to more closely represent a potential deployable system. Field testing will be performed to verify scaling predictions. Following successful demonstration of system performance within predictions, the system will be deployed to the SOR for simultaneous collection with existing SOR narrow field of view sensor systems. The goal of this testing will be to demonstrate the ability to use the wide field of view system to detect dim objects and immediately queue SOR high-resolution systems for further, time-critical detailed observations. Phase II work will also include the development and demonstration of prototype user controls and reporting systems, and the development of modifications and procedures to support a deployable operational system.

PHASE I: Deliver a mathematical model of the system design. In-depth examination of technology-related assumptions will be performed and validated. Develop simulation tools based on these existing mathematical models that will provide performance predictions for various candidate sub-configurations.

PHASE II: Demonstrate the ability to use the wide field of view system to detect dim objects and immediately queue SOR high-resolution systems for further, time-critical detailed observations. Phase II work will also include the development and demonstration of prototype user controls and reporting systems, and the development of modifications and procedures to support a deployable operational system.

PHASE III DUAL USE APPLICATIONS: Phase III work will build on "lessons learned" from Phases I and II to fully develop an operational scaled system prototype that can be easily deployed to one of USSTRATCOM's electro-optical surveillance sites.

REFERENCES:
1. Tony Hallas, "Chasing The Curve," Astronomy, Kalmbach Publishing Co., Apr 2012.

2. Study of Potential Spacecraft Target Near Earth Asteroids, Whiteley, AFRL-SR-AR-TR-06-0042.

3. Advances in Imaging and Electron Physics, Hawkes, V145, CEMES-CNRS, Elsevier.

KEYWORDS: wide field space surveillance, space situational awareness, unconventional telescope, persistent, timely

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AF141-019 TITLE: Battlefield Airmen (BA) Mission Recorder

KEY TECHNOLOGY AREA(S): Infosystems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type

of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop and demonstrate a device that can record essential information from special operations missions in order to perform mission analysis/debriefing, enhance operational procedures, and improve BA training and mission rehearsals.

DESCRIPTION: Battlefield Airmen missions range from Close Air Support, to field surveys, to direct combat. These special operations are typically high stress and rely on the individual operator's memory of actual events for follow-on actions, like mission debriefing, tactics improvements, training, and future mission rehearsals. Unfortunately, operator memory can't always be relied upon due to detrimental factors such as the fast-paced nature and stressful dynamics of special ops missions; war casualties; the vast amount of detailed information to be remembered (time, location, who said what to whom, etc.); time lag after conclusion of operations (resulting in inability to remember key details); and individual operators' mental capacity to accurately recollect events.

The purpose of this effort is to overcome those deficiencies by developing a robust capability that captures critical elements of voice (radio communications) and location of each BA action. The mission recording technology would serve a very similar function to that of an aircraft "black box."

Mission recording technology is used regularly in aircraft and other systems to record vital communications and other system information. This recorded data is valuable for post-mission debriefing, to develop training scenarios, and to review missions and improve operational tactics, techniques, and procedures (TTP). BA warfighters have been at the forefront of recent operations in Iraq and Afghanistan. Those operations revealed a need for a capability to record key aspects of their missions, yet that capability does not exist.

There are many different types of recorders in industry, but none has the functionality needed for BA missions. Current state-of-the-art (SoA) recorders do have the capability to record audio through a variety of input methods and recording features; however, they specifically lack integration with operational radios, as well as integration with GPS time and location stamp.

What is needed is a capability which can interface with the equipment carried by BA operators in order to capture incoming and outgoing radio communications. If the technology solution is carried by the operator it must plug in-line with the operator's radio and headset through the standard jack. In other words, such a solution would connect to the radio and provide the same standard jack as an output for communication to a push-to-talk and headset. If the technology solution is not carried by the operator, it must function from a secure environment and be easily accessible to operators when needed. Audio format must be a common format like WAV or MP3 so it's easily compatible with existing playback equipment. In addition to radio voice communications, the device should record the geographic position (GPS coordinates) and time of individual radio voice segments.

The recorder must be radio and headset agnostic (if carried by the operator), simple to use, encrypt the data, include a zeroize function (quickly and permanently erase data), and must not require external processing in order to operate. It also must function under a variety of environmental conditions such as rain, snow, high humidity, and ambient temperatures ranging from 0 degrees F to 110 degrees F. The recorder should require low power and if carried by the operator, draw it from the radios, i.e., no separate batteries for the recorder. Currently, operational radios have the ability to support power draw by external devices. Playback/mission analysis would not occur on the recorder, but on a computer with the proper software. Data encryption shall use DoD-approved methods to protect SECRET and below information. Use of a commercial standard (like AES) will be acceptable for any Phase I prototypes developed. Future versions of the Mission Recorder should allow the option of recording two radios through one technology solution.

PHASE I: Define the system requirements. Identify appropriate components to create a system design. Analyze the software necessary to enable the system to work. Propose a design to be built and demonstrated during Phase II. Demonstration of laboratory breadboard prototype hardware during Phase I is highly desired, but not required.

PHASE II: Build and demonstrate the recorder in a relevant environment. Recorder must meet requirements as stated in description above. Additionally, design should show significant consideration for human factors, including, but not limited to: size, weight, power, minimal cable management, and ambidexterity. Expected Technology Readiness Level of the recorder by the end of Phase II is TRL 6, and preferably TRL 7.

PHASE III DUAL USE APPLICATIONS: Military Application: Special tactics missions; anti-terrorist actions; urban warfare; team reconnaissance. Commercial Application: Law enforcement; homeland security; fire-fighting; hostage-rescue; fast-paced team activities that could benefit from forensic analysis of what transpired.

REFERENCES:

1. Battlefield Air Operations Kit, Increment II Capabilities Development Document, 19 November 2009.

2. Guardian Angels, Initial Capabilities Document, March 2010.

3. Battlefield Airmen, ISR Journal, August 2004.

KEYWORDS: Battlefield Airmen (BA), Battlefield Air Operations (BAO), BAO Kit, recorder

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AF141-020 TITLE: Improved Computerized Ground Forces for Close Air Support Training

KEY TECHNOLOGY AREA(S): Human systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop and demonstrate intelligent agents to interact within a computer generated forces suite for training aid use in Joint Terminal Attack Controller Training simulated environment.

DESCRIPTION: In current military operations our missions have become more complex and dynamic than they have been in the past. Given the nature of current operations the requirements for training and simulation is also accelerated. Our warfighters work with many different assets and therefore they should have the opportunity to train with the same assets they go to war with. Close Air Support (CAS) is one of the most challenging pursuits in combat today. It is challenging to train to CAS in a simulator due to the number of personnel required to attain a quality training experience. CAS players may include fast jets, unmanned aircraft, ground controllers and operation centers. Given the current ops tempo and availability of joint and distributed training opportunities, intelligent agents that work within CGFs would be tremendously valuable to assist in CAS training scenarios. Even if the personnel resources were available for all trainees to partake in an exercise, it is difficult to attain quality training for all players.

The current state-of-the-art simulator available for Joint Terminal Attack Controller (JTAC) training is the Indirect Fire Forward Observer Trainer (I-FACT^TM). In order to use this simulation system, the non-training audience is required to be very large so that a robust and dynamic training environment can be replicated. This presents a technology gap that if filled will make training both more efficient and effective. To fulfill this gap, intelligent agents that work within a simulated environment using published simulation standards need to be developed.

Presently, the state-of-the-art for agents and intelligent role players exist in domains outside of military simulation. These agents are not programmed to interact using simulation standards. Furthermore, present state-of-the-art for intelligent agents do not behave appropriately for the military mission set; agents need to provide feedback using doctrinally correct responses. The desired end-state for this effort is the development of a prototype intelligent agent that will use the appropriate protocols to work within a CGF software suite. This will in turn be seamlessly integrated as white force assets into a government or commercial simulated training environment.

This effort aims to limit the white force or training aide assets required to provide immersive and realistic training for warfighters who support a CAS mission and for this effort specifically the JTAC. The primary focus of this work is to demonstrate the injection of white-force role players into a CGF that communicate and behave in a realistic manner to provide robust and cost-efficient training opportunities. The technical work associated with this effort should ensure that interoperability training standards are used. The modeled entities should be constructed synthetically and formatted so that both government and COTS systems may be used in parallel.

PHASE I: Identify and document CAS-related missions that the JTAC warfighters are expected to engage in with U.S. and allied partners. Identify and document possible white-force role players to be injected into a CGF. Develop and demonstrate a prototype of a functioning white force injected into a CGF for a JTAC-related CAS mission.

PHASE II: Upon successful demonstration in the Phase I effort, the white force agent will be refined, fully developed, and tested in a simulated environment. In addition, an additional agent will be developed to support an additional white force role. Both agents will be demonstrated in simulated training environment. Three CAS test scenarios will be developed that utilize the injected white force agents into a CGF.

PHASE III DUAL USE APPLICATIONS: This effort will provide an array of intelligent role players injected into CGFs to stimulate training environments for ground forces, to include Tactical Air Control Party (TACP), Air Battle Managers (ABM), Air Support Operations Center, and Air Operations Center warfighters.

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KEYWORDS: Command and Control Training, Computer Generated Forces, Close Air Support, Joint Terminal Attack Controller Training, Intelligent Agent, Cognitive Modeling

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AF141-021 TITLE: Holographic Lightfield 3D Display Metrology (HL3DM)

KEY TECHNOLOGY AREA(S): Human systems

OBJECTIVE: Develop test and evaluation methodology for holographic lightfield 3D displays with an automated measurement system to support comparisons of prototypes emerging from research, to enable robust calibration, and to perform product acceptance testing.

DESCRIPTION: Advanced FoLD 3D visualization systems, that enable multi-user full-parallax viewing of complex 3D data without eyewear, are being developed with the aim of increasing the productivity of operators and analysts in C2 Operations Centers. FoLD approaches have many potential advantages over the more common stereoscopic 3D (S3D) displays, including improved comfort and perception. FoLD systems achieve these user-acceptance improvements by (a) correcting S3D's incongruous accommodative, vergence and motion parallax depth cues and (b) eliminating the need for 3D spectacles (enabling eye-contact and non-verbal gesture communication). Full parallax multi-perspective lightfield 3D displays could also enhance collaborations and shared understanding of multi-layer 3D data sets in other application areas, including military intelligence, medical training, molecular research, mineral geology, and similar civil big-data environments.

Research towards these emerging eye-strain and nausea-free FoLD systems involves novel holographic, volumetric, multi-planar depthcube, integral imaging, and other lightfield display types which have been demonstrated as laboratory prototypes. Further hardware and software maturation is necessary for successful technology transition and commercialization. However, progress is currently restrained by a lack of validated metrics (physical and perceptual) and by a lack of testing protocols based on realistic user content and scenarios. Rapid, inexpensive physical measurement methodologies are required to guide research spirals, display calibration, and product acceptance. An automated measurement approach is needed to reduce the costs associated with making the large number of measurements required to describe display depth and lateral image quality from all pupil-pair positions within a reasonably large (30x30-deg to 90x90-deg) image viewing zone. Proposed approaches to FoLD metrology should address the multidisciplinary nature of display test and evaluation (T&E). Human visual perception needs to be convincingly addressed in all new physical (instrumental) measurement procedures.

Completely new classes of display technology, like FoLD, have gone through a similar phase. For example, the digital pixelated flat panel displays (FPD) class of 2D displays went through this metrics and metrology development phase in the early 1990s. This development was led in DoD by AFRL. By about 2004, the main 2D display technology on the planet (by units shipped and dollar sales) transitioned from the analog cathode ray tube (CRT) class to the FPD class. This epochal shift from CRTs to FPDs could not have occurred without the FPD T&E methodologies and standards. The overall objective of this topic is to expedite a similar transition in 3D displays from the S3D class to the FoLD class.

Performance metrics for physical measurements on FoLD systems include analogues to those developed for 2D displays: luminance, luminance contrast color uniformity, resolution, extinction ratio, refresh rate and distortion. Novel metrics needing to be added for the FoLD 3D class include depth acuity, depth contrast sensitivity, and full parallax commanded by head position in the lightfield. Special attention should be paid to calibration schemes and to sampling schemes to adequately describe display performance. New metrics may be proposed for the comparison of 2D, S3D and FoLD systems. Standards for FoLD 3D test and evaluation are incomplete; their development and vetting for inclusion in the display metrology standard maintained by the Society for Information Display (SID) is a secondary goal of this topic.

No government facilities or equipment will be provided.

PHASE I: Develop test and evaluation methodology for holographic and other light field 3D displays. Design an automated procedure for measuring the quality of FoLD systems. Deliverables shall include a review of literature and relevant technologies, a proposed strategy for optimizing the automated measurement procedure, a mature system design, and a draft handbook for FoLD test and evaluation.

PHASE II: Build and deliver the display measurement system designed in Phase I. Verify by demonstration that the measurement system is suitable for FoLD 3D visualization research, system calibration, and product acceptance testing. Obtain industry feedback and expand Phase draft handbook into a "Handbook FoLD Test & Evaluation Methodologies."

PHASE III DUAL USE APPLICATIONS: Develop a formal standard for FoLD test & evaluation methodology to enable transition and transfer of full-parallax 3D displays to military and civilian applications ranging from geospatial representations to modeling to design. Publish the standard via an international display metrology committee.

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KEYWORDS: test and evaluation, Field-of-Light Display, FoLD, hologram, light field, integral imaging, swept volume, depth cube, novel metrics, real world 3D

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AF141-023 TITLE: Voice-Enabled Agent for Realistic Integrated Combat Operations Training

KEY TECHNOLOGY AREA(S): Air Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop and demonstrate a voice-enabled intelligent agent to improve the realism of integrated combat operations training and rehearsal within the Air Support Operations Center.

DESCRIPTION: In today’s asymmetric combat operations, the integration and interoperability of various mission areas of the Command and Control domain is growing. The state-of-the-art in training and deployment preparation for these constituent mission areas is to train the missions as separate stovepiped communities using live and simulated assets that are not consistently available. There are some limited opportunities for the various communities to interact with one another via a distributed network, but the availability of appropriate technologies, other players and timely scheduling of activities jeopardizes persistence in distributed training for these mission areas today. This topic is seeking a method to establish capabilities for each mission area to realistically and routinely train as if they were interoperating as they would do in theater. One of the most salient missing pieces to achieve realistic training is the lack of realistic voice-enabled agents that can regularly play the role of other trainees, wingmen, entities, and coordination agencies. The current state-of- the-art in linguistic modeling does not provide a mechanism for intelligent agents to communicate in a realistic manner using voice within simulation environments. Voice-enabled intelligent agents are typically developed in a closed environment that does not take systems like military simulators into account. The voice agent developed in this effort must be designed using industry standards to effectively interact within a simulation environment. During Phase I the voice agent should be a position that is either within the ASOC or that externally coordinates with the ASOC. This effort will develop a flexible voice-enabled agent technology to support training in and across the mission areas identified above. This effort will develop methods to capture real-world communication and coordination instances and develop software models for agents and teammates that can realistically communicate and coordinate training events as though human players were present. While we envision the developed agents from this effort to improve the realism of training in these mission areas directly, there is also a great potential that these agents can also provide realistic communication instances for an integrated Live, Virtual, and Constructive (LVC) deployment preparation and training capability for the constituent communities of practice.

PHASE I: This phase will identify content related to the ASOC internal or external operators for the development effort. In addition, Phase I will develop a rudimentary proof-of-concept desktop exemplar of the training and rehearsal concept to be fully developed in the Phase II effort. Develop preliminary transition plan.

PHASE II: Prioritize missions for scenario and content development. Evaluate scenarios in the environment focusing initially in the interaction between aircraft, ASOCs, and JTACs on the ground, then RPA coord and other air traffic control and coord entities as synthetic players. Evaluations will quantify training effectiveness and mission readiness enhancement resulting from the environment. Training transfer to live events and exercises will be assessed. Refine transition plan.

PHASE III DUAL USE APPLICATIONS: Uniquely capable and cost-effective training and rehearsal capability that can be included as a part of live and virtual training and rehearsal, which does not exist today for operational combat training. No similar approach to train multi-role and other manned/unmanned aircraft.

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KEYWORDS: Intelligent Agents, Linguistic Agents, Language Processing, Voice Enabled Agents, Radio Procedures, Command Control and Coordination, Team Training

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AF141-024 TITLE: Adaptive Screen Materials for Image Projection

KEY TECHNOLOGY AREA(S): Human systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Research and develop a means of changing the gain of screen materials used for front-projected imagery in large-scale immersive simulation environments.

DESCRIPTION: In immersive training simulation environments, the primary stimuli presented to participants consists of visual imagery or cues. Some large-scale simulation environments are configured such that the imagery is front-projected on screens that (except for the floor) may partially or fully surround trainees. Some such environments are configured as large spherical or hemispherical domes in which the profile of the screen surface describes a compound curve. Such environments may be used for training both day and night operations. When training for day operations, a screen with high gain (e.g., high surface reflectivity), coupled with a set of projectors having high output, may be desirable for credible immersion. When training for night operations, participants may employ real night vision imaging devices ("NVGs") to view night scenes projected on the screen, e.g., the NVGs are stimulated by the projected scene and produce intensified imagery. Ideally the intensified imagery seen in the simulator will credibly match the imagery that the NVGs would produce when used in a corresponding operational night environment. At the same time, the projected night scene must appear realistic to the unaided eye. NVGs are very sensitive, so when using screen materials with high gain, filters must be used or projector settings must be changed to greatly reduce scene brightness. Such approaches may result in color artificialities and/or projectors operating near the extreme lower end of their brightness gamut, causing limited remaining available dynamic range and imagery that appears unrealistic to the unaided eye. A front projection screen surface having very low gain for night environments would allow image projectors to operate at more normal settings, permitting greater dynamic range while also giving imagery appearing more realistic both through the NVG and to the unaided eye.

Current state-of-the-art does not allow for day and night (to include NVGs) training in the same immersive space, it requires two separate environments. This effort is focused on developing an adaptive screen material that can be leveraged for both day and night operations. Space and cost realities may prevent the luxury of two separate simulators, one dedicated only to day environments and the other only to night; so, a non-emissive, non-specular screen with gain that is rapidly and continuously variable between high and low values by external means, somewhat like a chameleon skin, is desirable. Such gain must be uniform across the entire screen surface and must not vary with viewing angle. Simulators in which this screen surface might be used could be deployable, and could be configured as domes ranging from three to five meters in diameter. In some simulators, the screen surface could be made of a tight-weave fabric mounted over tubular frames, the smooth concave surface being formed by differential air pressure. Therefore, a screen with adjustable gain that is foldable and that can conform to compound curves (segment of a sphere) is desirable. Manufacturability, scalability, durability and affordability also are desirable features. Means of adjusting gain must not constitute any hazard to participants operating in such environments, nor may such means generate RF noise.

PHASE I: Research, define, compare and document technical capabilities and options. Determine a screen material concept capable of meeting all requirements in "Description" for immersive day, twilight and night simulation environments. Develop preliminary transition plan and business case analysis.

PHASE II: Demonstrate the proposed Phase I design concept with a prototype screen having an area of at least 3 square meters and that is scalable. Appearance of the imagery as viewed both with NVGs and by the unaided eye over a dynamic range spanning day to night is a key consideration. Submit a complete technical report documenting all work under the effort. Refine transition plan and business case analysis.

PHASE III DUAL USE APPLICATIONS: Military: Any training simulation system requiring realistic day, twilight and night environments for dismounted trainee participants. Examples: USAF JTAC Simulator; US Army Dismounted Soldier Simulator. Commercial: Entertainment and motion picture industry, also training or educational.

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KEYWORDS: projection screen, screen gain, variable reflectance, simulator imagery, front-projected night visual display dynamic range

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AF141-025 TITLE: Adaptive Instruction Authoring Tools

KEY TECHNOLOGY AREA(S): Information Systems Technology

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop and demonstrate tools that will allow subject matter experts (SMEs), instructional system designers (ISDs) and software engineers to produce simulation-based intelligent tutors and adaptive instruction more efficiently.

DESCRIPTION: The impact of intelligent tutoring systems and other forms of adaptive training technologies for promoting learning and subsequent performance has been shown a number of times in traditional classroom content areas such as reading and mathematics. Several applications of adaptive training have also been attempted with some success in more operational contexts such as electronics troubleshooting, power systems maintenance, and, most recently, in information technology troubleshooting and maintenance (see Fletcher, 1988; McCarthy, 2008). However, the development time associated with the creation of these tutors and adaptive training is significant and to date has involved a substantial amount of machine and knowledge engineering to achieve the desired end results. Moreover, high sustainment costs associated with retooling the content layers in these systems as operational domains change, as well as a lack of open source tools to facilitate growth of content databases and to promote domain expert generation of new content, continue to limit growth of these systems in the field. These issues, along with a persistent emphasis on closed and proprietary "one-off" tools, content, and architectures, has limited the broader application of intelligent tutoring and adaptive training systems in the military and especially in more complex operational domains. Prior work has made progress in the use of machine learning (cf. Stevens-Adams, et al., 2010) or high-order languages (cf. Cohen, et al., 2005; St. Amant, et al., 2005; Ritter, et al., 2006) to reduce development and sustainment costs. However, these approaches have characteristics that limit their suitability in a military training environment. For example, SMEs have to take significant time off task to learn the systems needed to create and update content, and there is still a significant dependence on proprietary methods that are costly and keep content from being more open and sharable across similar domains. This effort will address a number of these limitations by creating tools for authoring and maintaining adaptive training systems. These tools should provide intuitive and easy to use methods to allow domain SMEs and other instructional design and content developers with relatively little experience in the underpinnings of tutors or adaptive training system architectures to develop and sustain training applications that promote the benefits associated with this kind of instruction and training. Further, the tools should assist the developers in the application of best practices in instructional science and events of instruction such that the system is both content and instructionally valid. Finally, the developer tools must permit a more open and sharable design for content and instruction such that content and instructional approaches can be generalized across similar content spaces and training contexts.

PHASE I: Summarize best practices/applications in intelligent tutoring and adaptive training. Identify key common and unique features. Conduct a capabilities/gap analysis. Develop recommendations and a design specification for a tool set addressing the gaps while supporting more open and user friendly training design and delivery. Identify a content domain of relevance for a Phase II demonstration.

PHASE II: Develop and demonstrate the tool set in the content domain identified in Phase I. Implement the tools in an adaptive training exemplar and conduct user and training impact assessments. Refine tools and the exemplar, identify a domain to evaluate the generalizability and reuse of content and instructional approaches and conduct initial evaluations. Document impact of the exemplars on development and sustainment costs and on trainee performance.

PHASE III DUAL USE APPLICATIONS: The tools will improve training dev/delivery response times in military training squadrons. The tools permit a broader use in complex civilian areas such as emergency response and manned and unmanned border security and infrastructure monitoring where adaptive instruction is sorely needed.

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KEYWORDS: Tutoring, system, adaptive, training, open training solutions, shareable content, guided instructional design

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AF141-026 TITLE: Distributed Mission Operations Gateway

KEY TECHNOLOGY AREA(S): Human systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors

are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop a DIS/HLA gateway to permit a variety of non-simulation standardized trainers to integrate with and operate on the Distributed Mission Operations Network (DMON) for training exercises.

DESCRIPTION: The Air Force uses a variety of training systems and simulators for space Command and Control (C2) operator training. These systems and simulators are "stove-piped," in that they used different hardware, operating systems, networking capabilities, and proprietary software. In addition, none of these systems are Distributed Interactive Simulation (DIS) or High Level Architecture (HLA) standard system configurations. Finally, each one differs considerably in its capabilities to support training. These differences drive high development and maintenance costs and also prohibit these systems from integrating with and operating on the DMON. The DMON is the USAF standard distributed simulation network. Further, these systems cannot be brought into the broader USAF and Air Education and Training Command (AETC) training enterprise architecture where a standard approach for operator training that employs an extensible architecture and commercial off-the-shelf (COTS) personal computer (PC) hardware and operating systems, is required. A current attempt to address some of the differences issues and to move toward a common training system structure is called the Standard Space Trainer or SST. The SST has been designed to facilitate the development and delivery of training services on an enterprise, to provide support to the coordination and conduct of training, and to facilitate content and system integration as additional services with a software development kit and a published applications interface specification. However, even the SST is not capable of participating in distributed training and rehearsal events for different space operations communities. With the costs to modify legacy training systems being untenable, there is a substantial opportunity exists to develop a DIS and HLA compliant gateway that will permit these systems, including the SST, to continue to operate natively, but to pass data to and from the gateway that would do the translation to and from the larger DMON enterprise. The developed gateway and software must be compliant with the Joint Federation Object Model (FOM) Specifications, IEEE Distributed Interactive Simulation (DIS) / High Level Architecture (HLA) standards, DoD network, connectivity and interoperability standards (IAW AFI 36-2251, Air Force Training System Management, 5 Jun 2009), and the current DMON standards.

PHASE I: Conduct a training systems and content analysis of candidates for DMO integration. For these candidates, conduct a training mission analysis to characterize data interfaces needed and alignment of training system functions with DMO events of merit. Develop a data specification for the types of data translation the gateway will need to accomplish to support accredited training across the DMON.

PHASE II: Develop and demonstrate a gateway that allows the candidate training systems to interoperate in DMO training events. The gateway should permit crews to interact with the combined trainer/DMO environment in real time, reacting to stimulus and also providing stimulus to others as part of the larger training event. Phase II will also demonstrate student performance tracking across training environments in DMO events.

PHASE III DUAL USE APPLICATIONS: Military: Gateway permits a broader range of legacy training systems to be part of larger enterprises. Commercial: Common data exchanges allowing a variety of non-industry-standard environments to support distributed training and gaming across virtual and constructive boundaries.

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KEYWORDS: Bridge, integrate, SST, DMO, training, integrated live, virtual, and constructive training and exercise

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AF141-027 TITLE: Operator Interface for Flexible Control of Automated Sensor Functions

KEY TECHNOLOGY AREA(S): Human systems

OBJECTIVE: Develop/evaluate a multiple unmanned air vehicle interface prototype that increases transparency of automated sensor systems and enables intuitive operator interactions to direct/tailor sensor operations in response to dynamic mission requirements.

DESCRIPTION: Automation is becoming a critical element of intelligence, surveillance, and reconnaissance (ISR) operations. Automatic target recognition in unmanned robotic combat vehicles has been particularly successful. Reliance on automated sensor features will become even more critical with the vision of one operator (or crew) simultaneously supervising multiple unmanned air vehicles (UAVs). Existing interfaces are inadequate for controlling multiple UAV/sensor systems. Moreover, research to date has focused on interfaces for supervisory control of the flight of multiple vehicles, not the associated sensor operations. Advanced sensors support a variety of missions such as real-time identification of forces, finding targets in cluttered environments, and aiding battle damage assessment. The interface to the sensor systems needs to enable the operator to efficiently and flexibly interact with the automation in order to refine the sensor's automation level, change sensor processing algorithms/parameters, and delegate new tasks and constraints based on the current situation. Specific examples include: a) operator contending with target signature variations by refining the target/sensor acquisition parameters (e.g., aspect, depression, etc.) and b) operator needing to rapidly insert a target identification request on-the-fly. The design approach needs to support such interactions in envisioned multi-UAV/sensor applications. In sum, the present effort focuses on developing a flexible, intuitive interface between a UAV operator and electro-optical/infrared (EO/IR) sensors, rather than developing sensor algorithms or hardware. Successful completion of Phase I will require delivery of a technical report that describes the selected representative UAV sensor automation system(s), the associated display/control features that have been designed and evaluated, and anticipated shortfalls, limitations, and tradeoffs of each solution(s). A feasibility demonstration is desirable, but not required.

Completion of this effort will involve identifying which parameters of a representative automated sensor algorithm/system can be adjusted, as well as which are the strongest contributors to improved UAV mission effectiveness across a variety of conditions. The effort should address, at a minimum, EO/IR sensors for whatever UAV platform/task/mission(s) the proposer chooses to focus the interface design/evaluation. (Any simulated or representative sensor system employed in support of this effort should maintain data at an unclassified level. Proposer should not require any government materials, equipment, data, or facilities.) There are also other factors useful to consider in the design of an operator/sensor interface. First, there will be unique challenges to supervise multi-target prosecution and aggregate the findings of sensors across multiple UAVs performing a collaborative mission. Since supervisory control of multiple UAVs will be cognitively demanding, the interface will need to provide an intuitive and rapid means of tailoring the sensors' functionality, as well as adequate visualization into the sensors' processing to maintain operator mode awareness of automation state, in addition to general situation awareness. Support tools that assist the operator in authoring and validating sensor modifications may also be useful. Any decision support aid needs to provide information when required by the operator (e.g., projecting the outcome of candidate adjustments, allowing evaluation of alternate courses of action, and identifying potential problems). Moreover, the interface needs to mitigate excessive workload in interacting with the sensor and avoid permitting unsafe or ineffective modifications. Constraints on bandwidth, as well as issues associated with highly automated systems (e.g., sensor's reliability and operator complacency), are also important to consider. Another objective is to determine how best to optimize operator expectations and tolerances for error.

PHASE I: Design and evaluate candidate display and control features for an operator/sensor interface appropriate for single operator control of multi-unmanned air vehicles/sensor systems. Generate a final report that describes the interface solution(s), evaluation results, and an experimental plan to establish usability improvements in Phase II. A feasibility demonstration is desirable, but not required.

PHASE II: For the best approach identified in Phase I, develop a prototype and perform iterative testing and refinement cycles, culminating in a proof-of-concept interface for multi-UAV/sensor applications. Conduct validation studies of the interface in high-fidelity simulations or operational tests to demonstrate payoffs in interaction flexibility, interaction speed, error reduction, workload management, etc.

PHASE III DUAL USE APPLICATIONS: Military applications include intelligence, surveillance and reconnaissance exploitation; mission planning; and sensor applications in unmanned air, ground and sea systems. Commercial applications include surveillance for homeland security, law enforcement, and industrial security.

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KEYWORDS: unmanned air vehicle, UAV, automation, operator interface, sensor, human factors, situation awareness, target recognition

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AF141-028 TITLE: Multimodal-Multidimensional image fusion for morphological and functional evaluation of the retina

KEY TECHNOLOGY AREA(S): Human systems

OBJECTIVE: Develop a software platform capable of integrating information collected over repeated experiments and from disparate sensors to facilitate the measurement of the physiological response of ocular-tissue to damaging levels of light.

DESCRIPTION: The technological fields of ocular imaging and visual functional testing are rapidly evolving as independent approaches for the investigation of ocular pathophysiology which can be applied to the investigation of laser damaged eyes. Imaging modalities such as the fundus camera, scanning laser ophthalmoscope, optical coherence tomography, hyperspectral, speckle and fluorescence imagers each reveal different pieces of information which need to be evaluated together as a whole in order to form a complete picture of the physiological processes which are modulated within the eye as a result of noxious levels of exposure to light. Furthermore, physiological changes, such as oxygen consumption which can be revealed through combined imaging, need to be spatially and temporally related to loss in visual function in order to fully appreciate the biochemical cascades and neurological consequences of light damage (Muqit, 2011). Additionally, information from visual functional testing techniques, such as multifocal pattern electroretinography, needs to be correlated to image data with a high degree of spatial precision. Therefore, the Air Force seeks the development of a software platform which facilitates integration of data from all relevant retinal imaging modalities used in the investigation of retinal laser damage and associated visual function testing. The software application should recognize and automatically import data presented to it in industry standard formats and also provide a framework for importation of custom image and functional-test data files.

Customized software which accomplishes some of the desired integration detailed above has been published. For example, images of the macula collected with spectral domain optical coherence tomography and confocal scanning laser ophthalmoscopy have been used in conjunction with fundus-controlled microperimetry to create functional maps of the macula. (Charbel Issa et al., 2010; Troeger et al., 2010) However, greater functionality to include advanced, customizable preprocessing techniques for noise and motion artifact suppression, plus edge enhancement techniques and tunable match criteria for image fusion based on retinal features, as well as gradients in illumination and reflectance, are needed. Furthermore, difference imaging which highlights subtle changes from baseline images should be enabled to allow automated retinal layer segmentation and characterization of laser lesions.

Merging and manipulating image sets of multiple scales, dimensions, magnification factors and total field of view will be very computationally intensive; therefore, the use of parallel processing schemes which leverage CUDA and/or other scalable multiprocessor approaches will be required.

PHASE I: Create a software development plan which identifies i/o formats associated with 2D and 3D imaging modalities and complementary visual function tests; delineates desirable preprocessing capabilities for noise reduction in native images; details technical approaches for image registration and data fusion; defines the graphical user interface for data management and outlines verification procedures.

PHASE II: This effort will include creation of a complete software specification, beta code generation, execution on a relevant parallel processor platform and documentation with a detailed design description and compilation dependencies for all algorithms and data structures. Finally, a verification test plan will be executed with representative retinal image data (government provided or approved) to ensure all the requirements identified in the software specification have been adequately addressed.

PHASE III DUAL USE APPLICATIONS: Beyond the study of changes in physiological function of the retina resulting from light induced damage, this technology will have widespread application to ophthalmic medical practice in general.

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KEYWORDS: image fusion, image registration, functional imaging, ophthalmic imaging, feature extraction, visual function

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AF141-029 TITLE: Mobile Motion Capture for Human Skeletal Modeling in Natural Environments

KEY TECHNOLOGY AREA(S): Human systems

OBJECTIVE: Develop hardware and/or software tools to accurately determine full body segment positions and orientations of a person performing various activities in natural indoor and outdoor environments.

DESCRIPTION: Full-body human motion capture has a variety of important applications within the Air Force and Department of Defense, as well as in numerous commercial industries, such as athletics, health care, and entertainment. AFRL applications include the creation of biofidelic avatar-based training scenarios and the collection of "ground-truth" data for research on human surveillance and tracking methods. Natural settings, including varying terrain, backgrounds, and clothing, are important to AFRL applications, where multiple sensor modalities are used coincidently (i.e., “sensor fusion”). For example, motion capture can serve as the ground truth for synchronized radar and video collections, where the background and clothing worn are critical to replicating in-field video feeds and the outdoor terrain is critical to replicating in-field radar returns.

Current full-body motion capture technology has limitations that inhibit its use in natural or real-world settings. The current gold standard in accuracy is optical motion capture, which relies on line of sight between multiple cameras with light emitting strobes and retro-reflective markers placed on the subject. Optical systems are, however, cumbersome to move and cannot be used with typical attire. Other motion capture technologies exist, each with their own limitations. Electromagnetic sensors provide accurate orientation and position, but are greatly limited by the range of the generated magnetic field. Inertial measure units (IMUs) increase portability, but are limited to orientation measurements only. Markerless motion capture methods focus on fitting a model to a silhouette extracted from 2-D video but are often inaccurate for precise motion analysis. Additional information, such as from a depth sensor (e.g., Microsoft Kinect) can be used to provide some 3-D information.

While advances in these areas have shown promise as a replacement to optical motion capture, to date commercial products that provide sufficient accuracy are still unavailable. AFRL is seeking innovative hardware and software tools that will result in the development of a motion capture technology that is: 1) mobile (can be relatively easily moved to various locations), 2) compatible with a variety of clothing, and 3) not restrictive of natural motion (e.g., untethered/wireless). In particular, we are interested in tools that fuse different hardware modalities. For example, an IMU-based motion capture system might be augmented with markerless motion capture techniques or a local positioning system to create a single motion capture system capable of accurate orientation and position tracking.

PHASE I: Develop an initial concept hardware and software design in order to accurately determine human segment positions and orientations under clothing in a natural environment. Demonstrate the ability to design and implement the technology through proof of concept.

PHASE II: Develop and demonstrate a fully functional prototype of the hardware/software system. Integrate all hardware so that it can be controlled from a single software interface. Validate the system’s accuracy through laboratory experiments.

PHASE III DUAL USE APPLICATIONS: The technology will allow the military to collect ground-truth human motion data in realistic operational environments to assist in human threat detection. The technology will provide researchers and doctors with a motion capture system that can record motion in realistic settings.

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KEYWORDS: motion capture, motion analysis, human modeling, pose estimation, inverse kinematics, inertial measurement units, electromagnetic tracking, markerless motion capture

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AF141-030 TITLE: Synthetic Task Environment for Primary & Secondary Assessment in Trauma Care

KEY TECHNOLOGY AREA(S): Human systems

OBJECTIVE: To develop and demonstrate a synthetic task environment for primary and secondary assessment in trauma care. This includes the capacity for creating/editing scenarios, recording performance and simulation data, and interoperating with external sims.

DESCRIPTION: Trauma care is an essential skill for medical professionals in the Department of Defense. The most critical aspect of trauma care is primary and secondary assessment of patients at first encounter. These assessments are made during every trauma case, and represent the first opportunity for medical professionals to impact long-term patient prognosis. Patient outcomes depend not only on the effectiveness of these assessments (doing them right), but also on the efficiency (doing them quickly). Providing opportunities to rehearse and hone these skills in a virtual environment will improve outcomes for warfighters on the battlefield by ensuring that the underlying competencies are well-learned and routinized to maximize the likelihood of a positive outcome for patients.

Importantly, it has been shown that medical professionals who are experts in trauma care do perform this initial assessment more quickly and accurately than novices and training leads to better performance (Holcomb, et al., 2002). At the same time, training opportunities are limited for many of the injuries that may be sustained on the battlefield, creating a need that can be partially addressed with simulation (Bruce, Bridges, & Holcomb, 2003). High-fidelity medical mannequins provide a valuable opportunity, but lower-fidelity training options may provide value for rehearsing many of the fundamental skills necessary to perform assessments quickly and accurately. Currently, such lower-fidelity environments are lacking. Lower-fidelity simulators have the potential to increase the efficiency of training by allowing for the rehearsal of critical skills that do not require the high-fidelity environment. That is, such technologies allow for the evaluation and efficient leveraging of a family of resources that provide the right level of fidelity for the training requirements.

The Air Force Research Laboratory is interested in virtual environments that can present medical professionals with trauma scenarios where the critical steps of primary and secondary assessment can be rehearsed. A useful simulation environment must be of sufficient fidelity to provide opportunities for meaningful rehearsal of critical skills and decision making.

To be of value in assessing the development and maintenance of skills, the virtual environment must also support the collection and recording of critical simulation and performance data and events. These data must be of high enough resolution and detail to permit after-action review and assessment, as well as replay of critical events and sequences. The simulation must also have the capacity to interoperate with external software to allow bi-directional communication of data. That is, the simulation must be able to both communicate state/event information to external components and be able to accept inputs (e.g., actions) as well. The critical aspect of this is to identify a standard communication protocol for passing this information into and out of the environment, preferably using an open-source standard. Finally, it should support authoring through an interface that can be used by medical subject matter experts to create and modify scenarios.

PHASE I: The Phase I deliverable will be a prototype system demonstrating the feasibility for a virtual environment to support primary and secondary trauma assessment. It should include a plan for practical development and deployment, and demonstrate appropriate data capture and interoperability.

PHASE II: The Phase II deliverable will build upon the Phase I prototype to develop, demonstrate, and validate a synthetic task environment (STE) that supports rehearsal of primary and secondary trauma assessment. The STE must include the capacity for creating and editing scenarios, and well as support interoperability with external software. The system should run on standard desktop computing software.

PHASE III DUAL USE APPLICATIONS: Can be leveraged for training interventions for trauma care that can prepare medical professionals for the unique situations and challenges associated with casualties in operational contexts. Simulations that help to prepare civilian medical professionals for the most severe cases they will see.

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KEYWORDS: Synthetic Task Environment, STE, Simulation, Virtual Environment, Trauma Care, Primary Assessment, Secondary Assessment

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AF141-031   TITLE: Adaptive, Immersive Training to Counter Deception and Denial Tactics, Techniques and Procedures (TTPs) for C4ISR Networks

KEY TECHNOLOGY AREA(S): Human systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop a cyber-training environment that represents current actual environments and can be easily adapted by the users to support different training requirements.

DESCRIPTION: Cyber warfare is no longer a nascent domain with few players and negligible consequences. In the past two decades, state and non-state actors have repeatedly demonstrated the capability and intent to exercise their influence through network operations. In addition, cyber security is recognized not only as a military domain, but as a civilian threat documented by President Obama’s 2009 Cyber Security Initiative (White House, 2009). Effective cyber security training is vital to develop the cyber force capable of protecting our interests at home and abroad.

Currently Air Force cyber training relies primarily on instructor-led classroom (stand-up) training, rudimentary exercises and scenarios conducted on previous-generation systems. Given the low level of technical complexity, current training systems are configurable by the instructors, and can be reset at will in the event of a failure or crash. These training networks are modeled after operational Air Force networks and include diverse elements such as routers, switches, Windows/Linux OSs, proxies, and firewalls through virtualization; however, they lack incorporation of the complexities of today's real-world environments (system load, number of actors, and breadth of applications). Additionally, there is no inherent capability within current training systems to effectively model and enable pattern recognition analysis and synthesis.

The current state-of-the-art technologies are largely centered on individual subject-based learning, platforms, and scenario-based war-gaming. While there is a vast array of products on the market today (e.g., gaming) that enable/support these learning areas, there is no known single technological solution which meets the Air Force need for a virtualized network environment that will integrate realistic network analysis, and attack and defense scenarios, into a deployable, modular platform to serve as a training tool for Air Force cyber operators.

To fill the gap between the current state-of-the-art and the desired end-state, research is required to advance the science in the areas of working within highly complex virtual environments, and when fielded includes the capability to incorporate evolving cognitive science developments.

The final training system should be virtualized in a manner that is compatible with the current Air Force Net and easy to deploy and reset. The training system should closely replicate the complexities of current real-world cyber environments. The network should include realistic traffic generation that is modifiable by an instructor. The network should represent a variety of devices and protocols. The system should include network attack and defense scenarios based on present-day exploits and tactics. Scenarios should be adaptive and include multiple learning pathways for differing skill levels. Scenarios should include simulated actors performing network attack and network defense functions. Instructors should be able to efficiently author new scenarios.

The result will be the ability to effectively model and enable pattern recognition analysis and synthesis. The system should enable the development of skills to mitigate adversarial attempts at blocking access for obtaining any critical threat information (e.g., information and INTEL of operations, communication, computer networks, documents of strategy and tactics, organizational diagrams via wired or wireless). The capabilities of this product should also include allowing for forensic analysis. The system capability should include the ability to simulate the effect of a variety of denial and deception tactics including cyber-attacks, embedding viruses in networks, or emplacing adversary sensors within Blue systems to obtain intelligence information, implement denial of service attacks, damages, or complete destruction of communication and computer networks.

PHASE I: Define the system requirements. Identify appropriate components to create a system design. Analyze the software necessary to enable the system to work. Propose a design to be built and demonstrated during Phase II. Demonstration of laboratory breadboard prototype hardware during Phase I is highly desired, but not required.

PHASE II: Build and demonstrate the training system in a relevant environment. The system must meet requirements as stated in description above. Additionally, design should show significant consideration for human factors, including, but not limited to: flexibility, modularity of design, adaptive to changing environments, tailorability and inclusion of cognitive science advancements. Level of the system by the end of Phase II is TRL 6, and preferably TRL 7.

PHASE III DUAL USE APPLICATIONS: Tools and technologies for cyber defense training are marketable and sought after in both the U.S. government and private industry.

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4. Deceiving Adversary Network Scanning Efforts Using Host-Based Deception, www.dtic.mil/dtic/tr/fulltext/u2/a502233.pdf, 50k, 2009-06-01.

KEYWORDS: virtualization, Network Defense, Network Offense, Training, Cyber, Realistic Traffic Generation, counter deception and denial, immersive training, training and rehearsal, modeling and simulation, forensic analysis.

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AF141-032 TITLE: Sharing of Intelligence and Planning Information for Multi-Agency Coordination

KEY TECHNOLOGY AREA(S): Human systems

OBJECTIVE: Develop human-computer interfaces to enhance multi-agency collaboration in response to world situations including foreign and non-government agencies. Improve information sharing to support diplomatic, information, military, and economic efforts.

DESCRIPTION: This effort aims to improve collaborative decision making for Political, Military, Economic, Social, Infrastructure and Information systems (PMESII) and Diplomatic, Information, Military, and Economic (DIME) efforts. The technology developed on this effort will provide a human-computer interface (envisioning software only) that encapsulates information and tools needed for PMESII decision making.

It should be able to create "mission pictures" at multiple levels of abstraction for decision makers in the field, at theater levels, and at higher levels. It should be able to transform data into a meaningful story that can be understood at a glance in many cases and provide representation of information quality to gage trust.

The encapsulation of PMESII information sources may result in a common operational picture (COP) that can (1) store, aggregate, and display data; 2) be flexible, modifiable, and extensible for multiple heterogeneous information streams; (3) support third-party capability integration; and (4) be license free. The concepts of the COP and related User-Defined Operational Picture (UDOP) are described more in the reference below by Mulgund and Landsman. As this capability will support crisis situations, as well as everyday actions, it will be important to strike an optimal balance of ease- of-use, flexibility, and decision support.

In addition to workflow support, the system should also have built-in collaboration capabilities between players who have a role in decision making and planning. PMESII decisions, and the actions that follow, cannot be performed in isolation. They require input from many diverse players including military, governmental, non-governmental, and foreign. This COP may serve as a collaboration environment in itself; however, other types of collaboration tools may be developed or leveraged. Shared situation awareness and coordination of distributed decision-makers through collaborative methodologies will help to avoid misunderstanding or conflicting actions.

One customer base for this research are Air and Space Operations Centers (AOCs); however, the capability could also find its way into other agencies involved in PMESII processes. The information sources, within databases (digital) and organizations (humans), are vast, so it will be important for the contractor to specify what sources they plan to use for the demonstration system. Note that the information sources chosen are not nearly as critical as the human-centric technologies developed.

Currently, decision makers do not have a unified capability for DIME operations. Even if they would have access to the tools that are available, they probably would not have the time to learn and use them. The PRIME system described in Lowrance & Murdock (2009) aimed to "support (PMESII) analysts and strategy planners in allowing them to directly explore the full range of consequences associated with candidate courses of action (COAs)."

Also today there is significant reliance on phone calls between people with established relationships, rather than people who may be most relevant to the situation. Voice communication will continue to be critical but is not necessarily the most effective or efficient collaboration method for each phase of decision making. Joint doctrine recognizes that the "sharing of information with relevant United States government (USG) agencies, foreign governments and security forces, interorganizational partners, non-government organizations (NGOs), and members of the private sector, has proved vital in recent operations" (Joint Publication 3-0, Joint Operations, page III-14).

PHASE I: Phase I shall include a storyboard outlining the display layouts and user interactions. The emphasis in this phase is on the design and not a prototype. A good human-computer interface should focus far more on the user needs than the software implementation issues. That said, a plan to implement the concepts in Phase II including software tools needed and system integration should be provided.

PHASE II: The researcher shall design, develop, and demonstrate a prototype tool that implements the Phase I methodologies applicable to a selected operations center. The technology development shall have a goal of technology readiness level (TRL) 6 at the end of Phase II. The researcher shall also detail the plan for the Phase III effort.

PHASE III DUAL USE APPLICATIONS: A robust, off-the-shelf situation awareness tool capable of depicting information for distributed organizations, both government and non-government entities. Applicable to first responders, border protection, financial/manufacturing industries, healthcare, transportation & communications networks.

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KEYWORDS: Interagency cooperation, non-governmental agencies, common operational picture, user-defined operational picture, operations center, collaboration, visualization, human-computer interfaces, human system interfaces.

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AF141-035 TITLE: Expand Data Transfer Rates within Legacy Aircraft (ERLA)

KEY TECHNOLOGY AREA(S): Electronics and Electronic Warfare

OBJECTIVE: Develop the capability to grow legacy aircraft mission capabilities by increasing the intercommunications data rate within the aircraft to at least 100 Mbps without the addition of new wire or cable infrastructure.

DESCRIPTION: The intercommunication data rate (IDR) of legacy aircraft is a limiting factor for transferring data between positions on the vehicle. Current missions have not required an increase in these rates. However, future planned capabilities, such as Advanced Tactical Data Links (ATDL), are highly likely to require a significant increase in IDR. This problem will impact many legacy aircraft and will inhibit the acceptance of new technologies by the respective program offices. Retrofitting legacy aircraft with fiber optics or adding additional signal transmission channel elements (e.g., copper wires or cables) is absolutely NOT an option due to cost, depot time, and considerations of space, weight and power. Wired deterministic data on MIL-STD-1553B, the primary data bus of choice for military avionics in legacy aircraft, is 1 Mbps per bus.[1] In order to support future planned capabilities, IDR needs to be orders of magnitude higher. Non-deterministic video triax cables were designed for low-resolution sensors and displays, limiting upgrades planned for cockpit vision systems and future programs. Prior efforts have demonstrated the potential for increasing bandwidth over MS1553B cabling.[2] At least one effort has demonstrated the possibility of increasing bandwidth on legacy aircraft using power lines, as well. This topic seeks further improvements in using all physical channels, especially in concert, to increase intra-aircraft data throughput. Several worldwide consumer electronics consortia, such as the Homeplug Powerline Alliance, Multimedia over Coax Alliance, and the HomeGrid Forum, have formed over the past several years that create ever more powerful transceiver card sets and equipment to increase data transfer rates within homes and buildings and vehicles without adding any new wiring or cables.[3] Leveraging these ever-more capable commercial concepts and technologies could enable affordability, sustainability, and technology refresh at such times as a particular aircraft program office needs more bandwidth. Innovative research is needed to increase intra-aircraft data bandwidth to over 100 Mbps/channel (threshold) or over 1 Gbps/channel (objective), where the channels comprise the currently installed complement of wiring, cables, and power lines.

Phase I ground testing should be sufficient (a) to validate the technical approach and (b) to support both identification of legacy fighter/bomber program requirements that require flight testing and development of a flight test plan.

Phase II ground testing should result in prototype unit(s) that could be provided to a program office for possible flight certification. Support for "flight test" during Phase II is anticipated to include basic test of non-interference with existing aircraft systems, some reliability tests, some tests of the ease of installation, and a test of the ability to quickly shut off the system if there is a problem. This could also consist of installing the data transfer units and troubleshooting any data transfer problems as needed. It is conceivable that the government would desire to conduct these tests in conjunction with other previously scheduled flight tests of fighter/bomber aircraft. If that cannot be worked, piggy-backing on flight tests of other Air Force vehicles will be explored. As a last resort, the use of cooperative tests with civilian aircraft will be considered. If no arrangements can be made, the small business will be relieved of flight test support requirements in Phase II.

PHASE I: A high-speed interface design for installed wiring is to be designed for avionics that takes into account reliability and maintainability issues. Simulation measurements of the design should be used as much as possible to demonstrate potential data rate improvements. A roadmap is required describing the threshold and objective performance, with product spirals shown as off-ramps.

PHASE II: Prototypes demonstrating the technology are to be developed, tested and delivered along with a revised roadmap for Phase III commercialization and transition. The Phase II prototypes should be sufficient to evaluate the potential to develop products to meet the needs for bandwidth growth in a range of military and civil applications. In addition, a draft logistics plan must be delivered. Support a flight test by installing the data transfer units and being available to troubleshoot problems.

PHASE III DUAL USE APPLICATIONS: Military applications include all defense aircraft, battle tanks, and many shipboard electronics. Need an infrastructure accessible by defense integrators to obtain COTS boards. Civil applications will be developed for video distribution markets, including aircraft, trains, and homes/buildings.

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3. (a) Homeplug Powerline Alliance, multimedia up to 500 Mbps over powerlines, http://www.homeplug.org/; (b) IEEE Standard: "IEEE 1901-2010 - IEEE Standard for Broadband over Power Line Networks: Medium Access Control and Physical Layer Specifications," http://standards.ieee.org/findstds/standard/1901-2010.html; (c) background on broadband over power line (BPL) devices is available at http://en.wikipedia.org/wiki/IEEE_1901; (d) Multimedia over Coax Alliance (MoCA), www.mocalliance.org; (e) Entropic chipsets and associated software for broadband multimedia distribution; Entropic MoCA 2.0 is a certified reference design capable of delivering MAC throughput from 400 Mbps up to 1 Gbps over a home's existing coaxial cables; data available at www.entropic.com; (f) G.hn home network technology family of standards developed under the International Telecommunication Union Telecommunication Standards sector (ITU-T) and promoted by the HomeGrid Forum (http://www.homegridforum.org/); data available at http://en.wikipedia.org/wiki/G.hn.

KEYWORDS: Intra-aircraft data transfer rates, bandwidth, legacy aircraft, adaptive high speed interface, MIL-STD-1553B, multi-medium transmission

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AF141-036   TITLE: Logistics Data Management, Error Handling, Corrective Action Framework

KEY TECHNOLOGY AREA(S): Information Systems Technology

OBJECTIVE: Develop an architecture, technology roadmap, and working prototype that operationalizes Logistics Systems Data Error Handling, Analytics, and Corrective Action Management Activities.

DESCRIPTION: Air Force IT system modernization efforts continue to highlight the growing need for robust, standards-based, open service-oriented architectures. There is a critical need to provide a foundational approach to complex data error analysis, exception handling, and corrective action behaviors while providing reliable and consistent analytics, integration, workflow, and collaboration to support those behaviors. Multiple initiatives and programs require this type of solution within the Logistics Enterprise and by allowing each to develop their own approach to error handling and resolution, they run the risk of developing redundant, divergent, and potentially incompatible architectures that are costly to sustain.

Solution should include an extensible methodology, architecture and tool suite for identifying, resolving, reporting, and managing data exceptions and errors that can be used across the Logistics Enterprise. Solution should assume a common view of data and provide tailored information to specific user groups, including differentiation between master data and transaction layer services necessary for daily operations. Solution should include analytics that facilitate root cause analysis of data anomalies. Strategic, operational and tactical points of view must be considered in the proposed model.

This product must address the following objectives:
• Support creation of a global, enterprise-wide framework sourced from non-standard, heterogeneous, multi-organizational, distributed, centralized, and federated IT systems.

• Production of a strategic, operational, and tactical product roadmap, to include the integration with, and to, DoD and Air Force data and metadata repositories.
• A software solution that addresses, at a tactical level, prioritization of transactions, transaction definition changes, and corrective actions based on changing mission needs.

The solution and commercially viable prototype must address the following technical challenges:
• Account for structured and unstructured data.
• Support scalable "product configuration" options and incremental fielding based on customized sizing, throughput, partitioning, reliability, data model inputs and options.
• Address the operational challenges of data synchronization, sequencing, drill downs, periodicity and timeliness.
• Address merging standards and best practices related to data collection and profiling methodologies, data mining, data categorization, data correlation, and data error resolution, to include reporting, measurement, and threshold monitoring.
• Extend emergent technologies that support features such as rule-based engines; data Extract, Transform and Load (ETL) principles; data hub/master data management; segregation of duties; workflow and notification management.
• Integrate with existing "help desk" structures, command specific escalation and release management activities, Business Intelligence (BI) infrastructure and Root Cause Analysis tools, and applicable Information Assurance and Certification/Accreditation laws, rules, and regulations.
• Address data problem identification, analysis/corrective actions and the use of predictive analysis to uncover and mitigate data anomalies.
• Propose extensible best-of-breed standards, topologies, and architectures to fulfill and field the recommended solution Air Force wide.

PHASE I: Submit a proof-of-concept architecture with concept paper, technology design, software prototype, and Phase II build plan. Include solution scenarios, realistic data sets, and technical issues/risks. Prototype software demonstrates use of configurable business rules/innovative data quality-related algorithms.

PHASE II: Mature the prototype, incorporate operational (transaction level) layered services, integrate Master Data Management, extend predictive analysis, and demonstrate full solution capabilities using multidimensional data and complex business scenarios. Deliver revisions to the conceptual framework, technology design, and technical issues. Deliver solution-based training, maintenance materials and an implementation plan based on operational data migration recommendations and considerations.

PHASE III DUAL USE APPLICATIONS: Extend and transition prototype to operational use across the Logistics Enterprise domain.

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1. Quality Assessment of Trustworthiness of AFMC Acquisition Data, Karhoff, Herman L., Mitre Corp., Sep 2007 (available through DTIC).

2. Handling Exception in Service Oriented Architecture, Zaina, Luciana A M, et.al.

KEYWORDS: exception handling, error correction, Service Oriented Architectures, Transaction Data Management, Quality of Service, SOA

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AF141-037 TITLE: Laser for Airborne Communications (LAC)

KEY TECHNOLOGY AREA(S): Battlespace Environments

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Free Space Optical (FSO) based communication system supporting very high bandwidth communications for the airborne and surface layers. Threshold: reliable long-distance communication among moving platforms in wide variety of weather conditions.

DESCRIPTION: The purpose of this topic is to explore innovative free space optical (FSO) based hardware and software approaches and implementations leading to improved theater level communications for increased warfighter situation awareness (SA) and mission assurance.

The battlefield/theater environment will require both air-to-air communication and air-to-surface (fixed and mobile) communication. Aerial platforms will include: airborne reconnaissance, command and control (C2) assets, UAV ranging in size and altitude from Global Hawk to Shadow, and airships. Threshold required surface platforms include fixed base installations, stationary military vehicles, and slow-moving or static dismounts.

An early system performance goal is for communication to moving ground vehicles, then moving to air-ground and air-air combinations. Threshold performance is for single link capability between platforms. Goal performance is for platforms to have the capability to communicate with multiple platforms, as required, to execute multiple mission scenarios and satisfy the desire to provide seamless, integrated net-centric capabilities to the forward edge of the battlespace. Crosslink ranges between aerial platforms should extend to greater than 200 km. Down/Up link range from aerial to ground assets should be capable of ranges greater than 50 km. The data capacity for aerial-to-aerial crosslinks and aerial-to-ground downlinks should be at least 10 Gb/s with a goal of 40 Gb/s. The data capacity surface to aerial vehicle uplinks should be at least 10 Gb/s. The systems should support at least 1 GigE data inputs with a goal of additionally supporting 10 GigE. Ability to handle additional inputs such as digital data from RF links greater than 200 Mb/s RF is a plus.

The system should provide very high reliability in all weather conditions, although certain threshold throughput limitations may be reduced in defined difficult weather states. This is anticipated to include a hybrid FSO/RF approach for optical links impaired by very high atmospheric attenuation. Other approaches, such as adaptive optics, will be considered. Reduced data throughput is acceptable in these cases. The FSO system should incorporate techniques to allow high data throughput even in times of high atmospheric turbulence. The system designs must meet eye safety regulations for commercial aviation altitudes and below.

The systems must provide means for point-to-point (1:1) and multicast (1:many) communications, to include multiple moving platforms operating in expected conditions (i.e., planned flight conditions, not to include emergency turning, climb/descent, or severe evasive actions).

The systems must be SWaP compatible with their respective aerial platform or ground asset. Finally, low unit production cost, system reliability and mission assurance will be key requirements.

PHASE I: Demonstrate gigabyte transfer and bi-directional gigabyte IP communications over a distance of at least 2 miles, with one platform in motion (roll NLT 15, pitch NLT 5, yaw NLT 3 degrees, elevation NLT 20', lateral motion NLT 15'). Detailed concept design to meet above performance. Address communication with LEO and GEO satellites from aerial and surface nodes. Provide Phase II design.

PHASE II: Complete critical design of the Phase II lab prototype hardware including any additional required supporting MS&A. A network model and baseline network performance model will be provided during Phase II. All proposed programs must include at least Phase II hardware for one air-to-air scenario and one air to ground scenario.

Fabricate the lab prototype to show level of performance achieved compared to stated government goals including SWaP, reliability and portability, expected to be at TRL 5.

PHASE III DUAL USE APPLICATIONS: TRL-8. Initial field testing using captive-carry hardware integrated onto commercial aircraft or comparable equipment for dynamic airborne evaluations. Following successful initial field testing, initial end item platforms will be identified and the FSO products be ruggedized for field operations.

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3. Andrews, L., Phillips, R., FINAL REPORT: CHANNEL CHARACTERIZATION FOR FREE-SPACE OPTICAL COMMUNICATIONS, UCF DARPA Project ID: 66016010.

KEYWORDS: laser-communications, high-speed communications, common data link, free space optical, high bandwidth, hybrid optical, RF, all weather, eye-safe

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AF141-038 TITLE: Layered Virtualization Detection of Malicious Software Behavior (“Inception”)

KEY TECHNOLOGY AREA(S): Information Systems Technology

OBJECTIVE: Create an appliance which uses one or more layers of Type 2 (software) virtualization within a Type 1 (‘bare metal’) Hypervisor infrastructure which uses introspection to foil virtualization-aware malware escape attempts.

DESCRIPTION: Modern malware (viruses, Trojans, etc.) will attempt to adapt to the environment they are executed in. For instance, many versions of modern malware are able to determine if they are being run within a virtualized machine due to measurable differences in performance, configuration and/or behavior between virtualized and physical platforms. This is commonly done for several different malicious purposes, such as attempting to deceive potential investigation attempts, or in order to escape from within a virtualized system to affect the underlying code, among other possibilities. In the second case, attempted escape from virtualization is an obvious risk to the provider of the virtualization, as well as any other virtualized systems being provided on the same hardware.

In order to add additional defensive capabilities to improve attempts to close every potential gap in virtualization’s emulation of normal operational environments, the creation of multiple-layer virtualization with awareness of what happens in which layer of the virtualization is desired.

In this architecture, malicious content would be allowed to attempt to escape from within one layer of virtualization, yet leave the host system unaffected. Specifically, if any behaviors beyond those few needed to operate the Type 2 virtualization are detected in this (or potentially other layers of virtualization beyond the initial), it can fairly be assumed that there is malicious behavior happening which should be stopped and/or investigated, in accordance to the risk acceptance of the organization providing the virtualization.

PHASE I: Build a Type-1 hypervisor with introspection containing a Type-2 hypervisor with introspection. Show a proof of concept indicating the Type-1 hypervisor stopping functioning if any unexpected behaviors occur outside the Type-2 hypervisor.

PHASE II: Further harden and instrument the infrastructure developed in Phase I. Develop performance metrics for a single Type-2 hypervisor, multiple Type-2s running in parallel, and multiple layers of nested Type-2s. Test the prototype against appropriate "jailbreak" exploits and malware to determine its actual properties.

PHASE III DUAL USE APPLICATIONS: Commercialize the product and provide it for sale or via open source license to DoD, IC and commercial purchasers. Additional business opportunities in training, subject matter expertise, etc., also exist.

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2. http://en.wikipedia.org/wiki/Virtualization.

3. http://theinvisiblethings.blogspot.com/2012/09/how-is-qubes-os-different-from.html (Note that this is not advocating Qubes OS, but provides one expert’s views on some of the risks in various virtualization products available today).

4. https://tails.boum.org. The Amnesic Incognito Live System (TAILS), using a two-layer virtualization system for confidentiality rather than integrity.

5. http://sourceforge.net/p/whonix/wiki/Home/. Another confidentiality-based project using two-layered virtualization.

KEYWORDS: virtualization, sandboxing, detonation chamber, malware detection, blue pill, red pill, malware, bare metal hypervisor infrastructure, Type 2 Virtualization, hypervisor

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AF141-039   TITLE: Process Level Virtualization for System Assurance

KEY TECHNOLOGY AREA(S): Information Systems Technology

OBJECTIVE: Assure the proper handling of information from cradle to grave by leveraging process level virtualization throughout the information life cycle. This should also reduce malware propagation and improve access control, among other useful features.

DESCRIPTION: Process level virtualization (such as Bromium’s “micro virtualization,” FreeBSD “Jails” or Qubes OS’ “AppVM,” among others) creates a virtual sandbox around chosen processes which prevent them from communicating with other processes other than in explicitly defined ways. This capability is potentially very useful for protecting the confidentiality and integrity of various of these processes and the information within them. Extended to an information work flow, these capabilities could support the assurance of information from cradle to grave.

Thus the challenge is to ensure protected data and information is made available to all relevant users via an assured process level virtualization capability. However, given the DoD CIO’s call that all future conflicts will be coalition conflicts, this capability must be able to interoperate with other solutions, regardless if they use these process level virtualization defenses or not.

Another aspect of the challenge is to make these capabilities mesh across multiple systems in information flows, some of which are subject to rapid change with little warning.

PHASE I: Identify and demonstrate proof-of-concept capability to appropriately separate processes across a notional or representational information life cycle across two or more computers. Show how the prototype protects the information and information flow from failure and/or compromise of various components in the flow.

PHASE II: Extend the Phase I proof of concept to realistic (10-1,000) node scales, address unanticipated users, changing information life cycle processes and dealing with systems which do not provide the same level(s) of process level virtualization defenses but are required as part of the work flow.

PHASE III DUAL USE APPLICATIONS: Work with DoD systems of record and commercial systems to improve the state of the practice to a realistic security model more resilient against propagation of exploits. May also be useful as a moderate- to high-assurance single system capability.

REFERENCES:
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2. http://labs.vmware.com/download/52/ (PowerPoint file, “Introduction to Virtual Machines".

3. http://www.bromium.com/.

4.http://qubes-os.org/.

5. http://www.freebsd.org/doc/handbook/jails.html.

6. http://theinvisiblethings.blogspot.com/2012/09/how-is-qubes-os-different-from.html.

KEYWORDS: Process level virtualization, jails, AppVM, microvirtualization, system segmentation, confidentiality protection

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AF141-040 TITLE: Establishing and Maintaining Mission Application Trust in a Shared Cloud

KEY TECHNOLOGY AREA(S): Information Systems Technology

OBJECTIVE: Develop the methods, techniques, and protocols to establish and maintain mission application trust, and the resulting mission application security, in a shared cloud infrastructure.

DESCRIPTION: The Air Force desires to utilize cloud computing for mission applications due to its significant cost reduction and scalability advantages, but needs to maintain the overall application security to a level equal to standalone systems. Trusted computing is an important field in cyber security and is an essential part of any mission-critical operation or secure electronic communication. Being able to verify the trust among, and the communications between, critical application services is paramount to preventing compromise of mission operations. The problem of establishing and maintaining trust is magnified in a cloud-based deployment, since the customer does not physically control the infrastructure, and applications from multiple customers are likely running simultaneously on any given infrastructure component. This is even true in a private cloud infrastructure, although the diversity of customer types may be less.

The infrastructure of the cloud is controlled and managed by the cloud provider and not the customer using the cloud's services. Virtualization is heavily relied upon by the cloud infrastructure and allows the provider the flexibility to run applications from multiple customers on the same physical hardware, and transparently move these applications to other more powerful, or less loaded, physical instances when performance needs grow.

An appropriately certified cloud provider will typically state to the customer some level of assurance that the base infrastructure is secure, but security-conscious customers need proof beyond the cloud provider's policy promise. Such a customer needs to know the base infrastructure is secure, and remains so, while their critical application runs. These applications need to continuously test the trust of the cloud infrastructure they are currently running on to ensure it has not been compromised, since the application could be migrated to a physically different part of the infrastructure at essentially any time. Also, many of these mission applications are distributed, and this trust must be communicated between the distributed components for the entire mission application to remain secure.

The goal of this effort is to provide customers methods to verify the integrity of their mission applications running on a cloud infrastructure not in their control, as well as to provide a means to securely collaborate between distributed application components within this cloud. Techniques must be provided to periodically maintain and reestablish the trust of an application component, and for an application component to determine if it has experienced a loss of trust. Upon an application component losing trust, this component should no longer be able to communicate with its previously trusted interconnected components. A method to communicate the trustworthiness between two application components and establish a trusted connection shall be developed. The end-to-end security established should be able to survive on a cloud infrastructure that is compromised by an adversary with intimate knowledge of the solution provided, and only allow operation on uncompromised portions. The methods and protocols must be resilient to an attack even if the entire technique is known.

PHASE I: Identify the typical application components in mission applications that are required to establish trust in a shared cloud infrastructure. Provide techniques to verify and maintain the trust of each individual application component in the overall system.

PHASE II: Develop a method to establish, verify, and maintain trust between the components outlined in Phase I to allow for trusted communication between components. Once trust is established between two devices, a trusted communication method must be demonstrated. A prototype of this system must demonstrate protection within a cloud infrastructure containing compromised systems with intimate knowledge of the protocol established.

PHASE III DUAL USE APPLICATIONS: Utilize the developed technologies to automate the process of assuring the trust across a large cloud infrastructure for a given mission application. This technology would also directly benefit industries where trust and privacy are essential to business.

REFERENCES:
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KEYWORDS: virtualization, cloud computing, cloud security, end-to-end trust, secure communications, information assurance, cloud

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AF141-041 TITLE: Granular Compute Cloud Architecture

KEY TECHNOLOGY AREA(S): Information Systems Technology

OBJECTIVE: Develop a general purpose compute cloud architecture that allows more granular and flexible allocation of cloud computing resources for secure cloud-based mission application development.

DESCRIPTION: All traditional virtualization technologies predate the cloud era, and have been designed to be backward compatible with existing systems at the binary level, thus making it easy to run any pre-cloud developed applications in the cloud. This approach has worked well, since the primary use of the cloud today is the outsourcing of traditional enterprise applications by cloud infrastructure providers that then supply these same applications back to customers as a service.

However, for new applications designed specifically for a cloud, these traditional virtualization platforms bring a lot of extraneous overhead. The traditional VM abstraction is at too low a level for a generic compute cloud and as a result requires a full-blown operating system in each VM instance. When looking at a cloud as a general computing resource where a new mission application can be developed to securely run, this requirement limits the flexibility of the mission application architecture. Also, it dramatically increases the cloud resources needed by the mission application in terms of memory and computational power, and increases the management requirements of the overall system.

Most multi-tasking operating systems limit the effects that one process can have upon other process in the system. Various system resources are protected and when a process ends (cleanly or otherwise) the resources held is reclaimed by the system. This process isolation model has made application development easier and safer, and has allowed an almost infinite number of applications to be independently developed for popular operating systems like Linux and Microsoft Windows. Unfortunately, most operating systems did not go far enough in preventing malicious applications from breaking process boundaries.

The Air Force needs a cloud infrastructure that allocates resources on a per process basis, as opposed to the current per operating systems basis. This would result in significant savings, since the operating system need not be duplicated for every virtualized application instance. Such a system must maintain a level of secure isolation that is similar to the isolation between operating system instances in the cloud today.

The goal of this effort is to provide the Air Force with a more granular cloud architecture which allows new mission applications the ability to be deployed utilizing drastically less computing resources, less management burden, and maintain a high level of security. Techniques must be provided to securely isolate application components allow them to be easily deployed within the cloud infrastructure. This secure isolation must be lightweight, operating systems agnostic, and impose a minimal computational resource cost as compared to traditional virtualization, yet provide comparable protections. Methods and protocols must be provided to allow flexible secure communications amongst the deployed application components.

PHASE I: Develop and perform a feasibility study to evaluate whether any existing AF applications can be scaled/migrated into a cloud environment. Document the requirements for applications to be "cloud-ready" and identify possible candidates. Identify several candidate applications that provide a reasonable sampling for development/testing within a proof-of-concept demonstration capability in Phase II.

PHASE II: Evaluate application isolation technologies for applicability within generalized cloud infrastructure. Evaluate various secure communication methods/protocols for inter-component communications. Design/implement compute cloud infrastructure to securely deploy application components. Demonstrate proof of concept prototype of secure application isolation of representative distributed mission app with reduced cloud infrastructure usage, while maintaining overall app isolation and security.

PHASE III DUAL USE APPLICATIONS: Utilize the developed technologies to implement & deploy a secure distributed mission application. This technology also directly benefits all customers of cloud infrastructure as they move away from traditional enterprise applications to enterprise applications designed specifically for the cloud.

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2. Russel, Rusty, “lguest: Implementing the little Linux hypervisor,” IBM OzLabs, http://landley.net/kdocs/ols/2007/ols2007v2-pages-173-178.pdf.

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KEYWORDS: Virtualization, Cloud Computing, Cloud Security, End-to-End Trust, Secure Communications, Information Assurance

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AF141-042 TITLE: Protected Execution in Cloud Environments (PECE)

KEY TECHNOLOGY AREA(S): Information Systems Technology

OBJECTIVE: Analyze, develop and test a protected execution system that assures integrity of systems, software, and data by preventing unintended or unauthorized leakage through compromised third-party cloud infrastructures.

DESCRIPTION: External attackers or malicious insiders can deploy a variety of attacks against cloud infrastructure to expose sensitive code and data [1]. These attacks include traditional exploits against cloud instances, firmware and hardware-based malware, and the injection of malicious hypervisors.

Three examples of these attacks include:
1. A modified hypervisor that undetectably hooks and modifies API calls and arbitrary memory addresses to analyze and alter software behavior.
2. An attack that modifies a program’s dependencies, such as a dynamic-linked library (DLL), to modify memory accesses, alter program behavior, and tamper with data.
3. A custom hypervisor that single-steps application execution, allowing an adversary to analyze or modify each instruction as it executes [2].

External adversaries or malicious insiders at the provider can use these attacks to analyze code, launch D5 effects, expose sensitive data, and modify software behavior. With little or no control over the environment, cloud consumers cannot prevent these attacks.

As military organizations migrate to the cloud, they may need to trust the integrity of their systems, software, and data to a third-party, the cloud provider. The cloud provider may be public (e.g. Amazon EC2, Rackspace, etc.) or private (e.g. other government organizations). Malicious insiders within the provider, or the provider themselves, may analyze, modify, and exfiltrate a cloud consumer’s code and data [3]. In addition, external attackers may gain access to the cloud through vulnerabilities and supply chain attacks. Since the consumer lacks control over the environment, they cannot prevent these attacks or protect their code and data. Cloud consumers would benefit from technology that defeats these attacks by allowing them to securely operate in untrusted cloud instances while assuring confidentiality, integrity, and availability.

PHASE I: Research the application of efficient techniques, such as obfuscation, to prevent the rapid analysis or modification of computations and data in cloud environments.

PHASE II: Develop a working system that can prevent unintended or unauthorized leakage of data due to compromised cloud infrastructure. The team shall also carry out comprehensive benchmarking experiments using representative usage scenarios of varying application programs and malicious software and demonstrate the advantages of this approach by comparing against existing tools and techniques.

PHASE III DUAL USE APPLICATIONS: Employ developed technologies to assure the ability of mission applications to operate in hostile cloud environments. This technology also benefits commercial industries where trust and privacy are essential to business.

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KEYWORDS: Virtualization, Cloud Computing, Cloud Security, Virtual Machine Monitoring, Information Assurance, Protected Execution System, Cloud Infrastructure Attacks

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AF141-043   TITLE: Fault Isolation in Hypervisors with Live Migration

KEY TECHNOLOGY AREA(S): Information Systems Technology

OBJECTIVE: To reduce the complexity and attack surface of commodity hypervisors and the virtual devices used by guest virtual machines without sacrificing live migration support.

DESCRIPTION: One of the tenets of Cloud Computing is the ability to host multiple virtual machine instances (owned by multiple parties) on the same physical hardware with guarantees that the different machines will be isolated from each other. These virtual machines can then migrate from one physical host to another for load balancing and reliability. By design these virtual machines are managed by a privileged hypervisor (also known as a Virtual Machine Monitor) that mediates accesses by the guests to shared physical resources through the use of virtual devices and prepares the guest state for live migration. Thus a compromise of either the hypervisor or the virtual devices can lead to a breakdown in the isolation guarantee and live migration capabilities. This weakness needs to be addressed.

This topic seeks to buttress the fault isolation guarantees provided by commodity hypervisors (i.e., Xen, KVM, VMWare, VirtualBox) by reducing the complexity of the hypervisor and virtual devices, and properly isolating the different components, while providing live migration support at the same time. Proper isolation implies that an attack on the hypervisor or virtual devices can only affect the virtual machine from which the attack originates. It must not lead to the Denial of Service for the other guest virtual machines for example. There exists a corpus of academic research towards privileged hypervisor minimization. These include DeHype [1], a design that separates the KVM hypervisor into privileged and unprivileged components and moved all of the unprivileged code down to user-space, and NoHype [2] that eliminates much of the privileged hypervisor among others. The limitation is lack of live migration support though.

For example, DeHype [1] moves much of the hypervisor code, including the memory manager, from kernel space down into the user-space. By doing so, there is a need for two separate Guest Physical Address to Host Physical Address mappings: the one held by the kernel, and the version that is held by the userspace component. The userspace component would propose changes to the mappings and the kernel verifies the proposed changes, and if valid, commits them into the Nested Page Tables / Extended Page Tables for use by the virtual machine. In this organization, both copies must be synchronized and must be migrated at the same time. This is currently not supported.

PHASE I: Design a virtualization platform that minimizes the attack surface of the hypervisor, virtual devices as well as support live migration. Define metrics used to measure success (e.g., DoS attack isolation, live migration latency, etc.). Develop and demonstrate a proof-of-concept prototype in preparation for Phase II.

PHASE II: Develop the prototype designed during Phase I and test it against the proposed metrics. The testing environment should be representative of a real cloud environment. Demonstrate the isolation properties using real-world vulnerabilities/exploits and demonstrate live migration.

PHASE III DUAL USE APPLICATIONS: Mature the prototype developed during Phase II and create a representative cloud computing environment using the new technology. Demonstrate its effectiveness (in terms of isolation and live migration) using both host-based and network-based attacks.

REFERENCES:
1. C. Wu, Z. Wang and X. Jiang. Taming Hosted Hypervisors with (Mostly) Deprivileged Execution. In Proceedings of the 20th Annual Network and Distributed System Security Symposium, February 2013.

2. J. Szefer, E. Keller, R. B. Lee, and J. Rexford. Eliminating the Hypervisor Attack Surface for a More Secure Cloud. In Proceedings of the 18th ACM Conference on Computer and Communications Security, October 2011.

KEYWORDS: Cloud Computing, Virtual Machine, Hypervisor, Live Migration, Isolation, Least Privilege, Attack Surface Minimization

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AF141-044 TITLE: Live Patching of Virtual Machines with Limited Guest Support

KEY TECHNOLOGY AREA(S): Information Systems Technology

OBJECTIVE: This topic seeks to advance the state of the art towards being able to apply patches to a running guest virtual machine directly from the hypervisor without specialized software running on the guest.

DESCRIPTION: Patch management plays an important role in ensuring the overall security posture of machines. Traditionally, enterprise level patch management is conducted through the use of privileged end-point software that runs on the manage system. The patches and configuration changes can then be pushed to the end-points from a central server. Patch management in Cloud Computing essentially follows the same concept where the same end-point software is installed onto the virtual machines. This same paradigm is used even for dormant virtual machine images that are not running [1,2]. Given the advancement of virtual machine introspection [3] techniques for digital forensics and malware analysis [4,5], there is an opportunity to investigate the ability to apply patches to a live virtual machine with limited or no guest support. In this manner, critical, user-managed, misconfigured or malfunctioning virtual machines can still receive critical patches or configuration updates.

This topic seeks to advance the state of the art towards being able to apply patches to a running guest virtual machine directly from the hypervisor without specialized software running on the guest. The proposed solution needs to have a sound argument for and evidence to support the notion that the patch will be applied and the guest will not be rendered unstable. Additional metrics, such as the kind or type of patches that can be applied or the size of a guest module (if necessary), should also be proposed when necessary.

PHASE I: Define the type or kind of patches that can be applied to a live virtual machine and a technique for patching. Develop and demonstrate live patching on a proof-of-concept prototype.

PHASE II: Develop the prototype designed during Phase I and test it against the proposed metrics. Demonstrate live patching of virtual machines from the hypervisor using real-world patches on COTS systems. Prepare for commercialization.

PHASE III DUAL USE APPLICATIONS: Work with the DoD to demonstrate that the prototype developed during Phase II can also be applied to DoD systems and software. Further demonstrate the capability through multiple Guest Operating System platforms, e.g., Windows 7, Ubuntu Linux, etc.

REFERENCES:
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2. Virtual Machine Servicing Tool (VMST) 2012. http://technet.microsoft.com/en-us/library/jj149757.aspx.

3. K. Nance, M. Bishop, and B. Hay, “Virtual Machine Introspection: Observation or Interference?,” IEEE Security and Privacy 6(5) pp. 32–37. September 2008.

4. T. Lengyel, J. Neumann, S. Maresca, B. Payne and A. Kiayias. “Virtual Machine Introspection in a Hybrid Honeypot Architecture.” In Proceedings of the 5th Workshop on Cyber Security Experiment and Test. August 2012.

5. D. Srinivasan, Z. Wang, X. Jiang and D. Xu. “Process Out-Grafting: An Efficient ‘Out-of-VM’ Approach for Fine-Grained Process Execution Monitoring.” In Proceedings of the 18th ACM Conference on Computer and Communications Security. October 2011.

KEYWORDS: Cloud Computing, Patch Management, Configuration Management, Virtual Machine Introspection, Active Introspection, Digital Forensics, Live Guest, Running Guest

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AF141-045 TITLE: Conformal High-Efficiency Emitter Systems Enhancement (CHEESE)

KEY TECHNOLOGY AREA(S): Electronics and Electronic Warfare

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors

are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop low- (to no-) protruding antennae for SWaP-constrained aerial platforms. Provide minimal penetration of platform skin and structure.

DESCRIPTION: Provide approach for minimal impact for SWaP-C constrained aerial platforms, especially small to medium UAS that may be employed as dedicated maneuvering communications relays and gateways. The frequencies of interest for the antennas can range from L-band to Ku-band and are primarily meant to support Line Of Sight (LOS) communications.

Conformal emitters reduce drag and, at times, detectability of the air platform; in some designs, weight, changes to platform skin and structure is lessened, but, generally, conformal emitters are more expensive to install due to the need for underside antenna structures. Consider placement of one or more improved conformal designs to maximize utility of emitter for warfighter use. Consider frequency spectrum efficiency, cost, ease of manufacture, decrease in effectiveness (because it is not in the slipstream and may be "hidden" within the structure) or partially reduced in effectiveness due to potential lack of backplane provided to traditional emitters by the platform's skin.

Recent advances by many SBIR and large antenna designers have not had a comparative examination. This SBIR would provide an across the board look at multiple designs, identify specific features, in conjunction with the IP holders, to compare and contrast design features.

PHASE I: Examine and compare top 10 emitter designs (from "paint-on" to flush-mounted but deep) with attention to emitted power, gain, weight, power usage, skin and structure penetration, detectability by adversary defensive and offensive system (using engineering and physics estimations); select two candidates or blends of best features of the original 10; develop and prototype candidate(s) alternatives.

PHASE II: Employing own and government or commercial or university laboratory, construct working prototype(s) for multiple military communications band. TRL-5/6 goal. Design, develop, and conduct laboratory or ground field test. Provide engineering approach for installation and testing on 2 or more candidate US Air Force model-designation-series (MDS) aircraft. Provide cost estimate for production of dual quantities of emitters for Phase III flight testing. TRL-6.

PHASE III DUAL USE APPLICATIONS: Flight test and report results using wide spectrum analysis; conduct cosite tests for selected US Air Force platform(s).

REFERENCES:
1. Pique, A., Auyeung, R., et al, Rapid Prototyping of Conformal Antenna Structures, http://www.princeton.edu/~spikelab/papers/027.pdf.

2. Gonzalez, M., Analysis of Conformal Antennas for Avionics Applications, Chalmers, DLR, Jan 2007.

3. Callus, Paul J., Conformal Load-Bearing Antenna Structure for Australian Defence Force Aircraft, http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA470328.

KEYWORDS: conformal antennas, load bearing antennas, affordable communications, L-band, C-band, Ku-band, S-band

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AF141-046 TITLE: Inverse Mission Planning of Aerial Communications Technologies (IMPACT)

KEY TECHNOLOGY AREA(S): Battlespace Environments

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Employ geospatial and mission-aware techniques to provide optimum coverage for all warfighters independent of mission criticality; reserve ability to prioritize surface communication needs. Reliable planning of airborne links increases survivability.

DESCRIPTION: Dedicated airborne relays and gateways are a relatively new addition to the battle space, and these are proving to be valued highly by both US and coalition ground forces. Having aerial platforms that, merely by virtue of their elevation above the ground communicator, provide 10 times or more RF effective range to communications devices used by our ground and special forces warfighters, allows cross-theater/cross-battle space communications and reachback to main Command & Control (C2) elements. Likewise, an airborne gateway/relay can provide extended C2 coverage for strike, rescue, and resupply missions within or entering/exiting the battle space. In order to take full advantage of these airborne gateway/relays, a robust mission planning approach is required to enable detailed planning, dynamic management and adaptive control of the enhanced communications and networking capability that is provided by these assets.

There are so many automated means employed on a regular basis today for complex networking and mission planning purposes that we no longer have to accept only a normalized approach to communications planning. It is now well within our reach to at least partially optimize assured RF coverage for all elements of a complex, changing, mobile set of forces. While it is not possible to establish a "ground truth" in cognitive networking for something happening in the future and something subject to continual change, we can vastly improve the state of communications if we begin to match up link quality and Quality-of-Service (QoS) for each air and ground element, with consideration given to the entire battle space, when geospatial, mission aware, and temporal factors, in addition to basic RF propagation factors, are considered. We can also "stretch" our mission planning to well beyond a safe radius of action for a given pair of transmitter-receivers, especially as we move to more Internet Protocol (IP) communications.

We must consider how missions are planned for joint and coalition forces using common planning tools. In many cases, specialized mission planning modules exist to control weapons delivery, navigation, threat avoidance, terrain following, etc. These modules are based on forward planning techniques which generally employ only a normalized approach for planning the specific mission. Unlike these specialized mission planning modules that support unit aircraft through forward planning techniques, the dedicated communications and network planning modules which are designed to integrate with current planning systems, might consider inverse planning techniques to serve a maximum number of ground users possible within the communications range of one or more dedicated airborne platforms. Such inverse planning techniques could employ an automated approach to communications and network planning through the assignment of critical factors, or weights, to ground users along with weight optimization schemes for prioritization of transmitter-receiver pairing. The Commander’s staff not only needs to know who the planned communicators are, but who MIGHT BECOME a user on short notice. Weighting of ground user (or others, non-relay nodes) mission priorities may need to be considered if the problem set shows a stretch must be made to fill all potential customer needs.

It will be vital to determine which factors can be normalized (considered at a base level, without specific outlier conditions considered). Radio characteristics may include: frequency, waveform, power, power amplifiers, antenna patterns, co-site issues, mode, etc. Antenna characteristics may include: multiple input/output (MIMO) versus single input/output (SISO), co-site factors, frequency, gain (transmit and receive), directionality, diplexing, etc. Some physical factors to be considered are: partial/full antenna blockage by wing/fuselage, aircraft state (both receiver and transmitter), terrain, and environment/weather. Propagation factors such as frequency sharing or isolation, and shared spectrum beyond effective ranges may also be considered in the solution.

PHASE I: Outline/select, in conjunction with SPOC/TPOC, factors for the planning problem. Deliver prototype IMPACT module, based on current unit-level mission planning tool for the communications node. Identify services needed from air, land, maritime forces' planning centers to determine the "customer set" and priorities.

PHASE II: Refine and test using modeling and simulation and RF emulation tools. In conjunction with unit-level mission planning office, select test cases; working with relevant airborne gateway/relay programs, validate problem set, run test cases. With SPOC/TPOC, select appropriate venue for live testing using existing field assets in live-virtual-constructive (LVC) environment.

PHASE III DUAL USE APPLICATIONS: Partner with AFLCMC/HBM (Airspace Mission Planning Division) to integrate IMPACT into Unit-Level Mission Planning and Force-Level Mission and Campaign Planning at Air Operations Centers (AOCs) and airborne gateway mission wings and squadrons.

REFERENCES:
1. Bonneau, R., Complex Cognitive Networking (multiple studies), AFOSR, 2010-2013.

2. Vangati, M., Optimization of displayed RF Coverage, USPTO No. 8185121, 22 May 2012.

3. Morentz, J., Desourdis, R., et al, Public Safety Integration Center, SAIC, www.emforum.org/pub/eiip/PSICWhitePaper.pdf.

4. Siradel, Volcano Propagation Model, http://www.siradel.com/1/volcano-software.aspx.

KEYWORDS: complex cognitive network, airborne communications, aerial layer network, mission planning, impact

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AF141-047 TITLE: Air Force Weather Mobile Application

KEY TECHNOLOGY AREA(S): Information Systems Technology

OBJECTIVE: Evaluate technologies, security and authentication mechanisms and services required to enable Air Force Weather (AFW) data and tailored products to be available to authorized and authenticated users on Android-OS (and potentially iOS) platforms.

DESCRIPTION: Bluetooth common access card (CAC) readers for Android (and others) smartphones and tablets are commercially available, and some configurations have already been analyzed by the Defense Information Systems Agency (DISA) (http://iase.disa.mil/stigs/net_perimeter/wireless/smartphone.html). However, it needs to be determined if all the required technology and approvals exist and only the Air Force Weather apps need to be written, or if there is a technology gap that must be solved first. And in the case of a technology gap, potential solution sets need to be identified and evaluated.

In this SBIR, we will investigate the current and near-term state of technology for military mobile applications to determine what is possible for supporting mobile application integration for Air Force Weather data and services. Specifically, the challenges of Android (and possibly other) mobile applications with Information Assurance (IA) requirements over mobile devices will be addressed for AFW web pages and services. Android applications and mobile devices have many challenges within DoD Information Assurance IT systems. Generally, a DoD IT system must apply for IA certification & accreditation (C&A) that have stringent guidance programs that must be addressed in order to receive an authority to operate (ATO) with a DoD Designated Approving Authority (DAA). This SBIR will investigate Cyber Security and IA best practices and determine how they are to be incorporated into the AFW application development process. When there is no solution resulting in a technology gap that must be addressed, potential solutions will be identified and evaluated.

For example, Android implements an application permission framework that provides the ability to control which operations are allowed for individual applications. This SBIR will determine the use of application permissions (e.g., obtain/grant access to capabilities of the Android device) and the rationale for defining new permissions for controlling inter-application access.

Using the DISA Android STIG and the Application Security and Development STIG as guidance for application authentication and access control, this SBIR will determine the approach for AFW Android mobile apps (e.g., multi-tier versus in-device) and identify the potential authentication points. Both the need for a DoD Public Key Infrastructure (PKI)-approved credentials and a CAC reader and password authentication will be addressed, as well as software security certificates, as an alternative to physical CAC authentication.

In addition, the SBIR will recommend solutions or identify technology gaps and potential solution sets for:
a. Use of standard Notice and Consent Banners
b. Data protection
  - Encryption for data/databases on the Android device
  - Encryption and integrity protection for data stored on and external SD card and/or alternatives to using an external SD card
c. Reverse engineering protection (e.g., file permissions)
d. Secure programming practices for
  - Input validation
  - Injection attack avoidance (e.g., SQL, command)
  - Digital signatures
  - Android NDK or Java JNI
  - Third-party libraries
e. Secure data communication
  - Transport Layer Security (TLS) utilization
  - Parameter content
f. Secure inter-app communication
  - Securing Android intents
  - Securing content providers
g. Secure application update process
h. Non-Android SDK applications

PHASE I: Determine if the technology and policy exists to deploy a secure authenticated AFW-WEBs application. If there is a technology gap, identify and evaluate potential solution sets. Design and demonstrate a prototype AFW-WEBS application on an Android device using approved authentication and authorization to securely access services and display product on a standalone and/or simulated network.

PHASE II: Develop a prototype that accesses and displays AFW-WEBS products and services, utilizing either CAC authentication or a software certificate to accomplish secure access over the NIPRnet environment and that can be fielded with authority to test (ATT). Demonstrate the suitability and effectiveness of this solution in exercises and test scenarios. The contractor will include in this effort the associated costs and schedule to demonstrate the AFW-WEBs mobile app to the user command.

PHASE III DUAL USE APPLICATIONS: Harden and integrate this mobile solution into the Air Force Weather Family of Systems. Demonstrate solution in an operational environment.

REFERENCES:

1. CAC Use on Mobile Devices; http://militarycac.com/mobile.htm.

2. US Air Force Weather Web Services (AFW-Webs) 15 November 2010; http://external.opengeospatial.org/twiki_public/pub/MetOceanDWG/MetOGCWorkshop3/AFWA_Brief_to_OGC_MDWG_-_Nov_2010.pdf.

3. Cummings Engineering - SecureSleeve; www.cummings-inc.com.

KEYWORDS: Air Force Weather, mobile secure applications, Android, iOS, tactical mobile applications, mobile device software, AFW-WEBs, secure data transmission

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AF141-048 TITLE: Integrating Tactical Weather Sensors with Mobile Devices and the AF Weather Enterprise

KEY TECHNOLOGY AREA(S): Information Systems Technology

OBJECTIVE: Evaluate technologies to enable Air Force Weather sensing technologies, data and services to be available to authorized/authenticated users on mobile devices and data collected from tactical sensors to be integrated within the AF Weather enterprise.

DESCRIPTION: This SBIR will focus on using mobile devices and applications to integrate first-in deployed capabilities for the combat weather teams into the greater Air Force Weather Family of Systems (AFWFS). Specifically, this topic will determine methods to more effectively exploit modern communication and weather-sensing technologies to support automated data collection, processing, and dissemination to augment and assist the combat weather team. For example, the ability to link the Iridium satellite phone data connectivity capability with an Air Force Weather mobile device and software application that goes beyond basic voice capabilities (i.e., calling in weather observations) will provide valuable point data from denied areas to assist local military operations.

In this SBIR, we will be investigating the current and near-term state of technology for military mobile applications to determine what is possible for supporting mobile application integration for Air Force Weather sensing technologies, data and services. This SBIR will identify and use Cyber Security and information assurance (IA) best practices and demonstrate their use in automated AFW data collection, processing, and dissemination using mobile applications. In addition, this SBIR will identify the challenges and any technology gaps related to the limitations of mobile devices relative to automated AFW data collection, processing, and dissemination. For the technology gaps, potential solutions will be identified and evaluated.

The SBIR will also evaluate:
a) Sharing data from an AFW mobile device and software application on a tactical/forward-deployed network to make it available to the Air Force Weather Agency (AFWA) and command and control (C2) systems.
b) Using the AFW mobile device and software application to further synthesize local and external meteorological data to allow for the development and tailoring of data products to share with other tactical/forward-deployed systems and users.
c) Integrating AFW mobile devices and software applications with additional tools and data resources (e.g., weather sensors such as the TMQ-53 and Weather Pods, and tactical hardware and software such as the Joint Environmental Toolkit) to more fully support the local users and systems.
d) Making an AFW mobile application available for download and use by warfighters to allow them to get the local observation, forecast, and radar/satellite imagery.
e) Having an AFW mobile application on warfighter mobile devices support weather warnings, advisories, and alerts to enhance safety for friendly forces.

PHASE I: Determine if the technology and policy exists to securely integrate weather data collected from tactical weather sensors (e.g., Kestrel) into the AFW enterprise. If there is a technology gap, identify and evaluate potential solution sets. Design and demonstrate a prototype application on a mobile platform that processes and disseminates such data onto a standalone or simulated network.

PHASE II: Develop a prototype that securely integrates weather data collected from tactical weather sensors (e.g., Kestrel) on a tactical/forward deployed network to make available to the AFW enterprise, C2 user, and local warfighter/unit. Demonstrate the suitability and effectiveness of this solution with authority to test (ATT) in exercises and test scenarios. The contractor will include in this effort the associated costs and schedule to demonstrate the solution to the user command.

PHASE III DUAL USE APPLICATIONS: Harden and integrate this mobile tactical weather collection solution into the Air Force Weather Family of Systems. Demonstrate solution in an operational environment.

REFERENCES:
1. Kestrel Weather Meters; http://www.kestrelmeters.com/.

2. Team weathers the mission; http://www.af.mil/news/story.asp?id=123026095.

3. ESC Weather Programs; http://www.afceaboston.com/documents/events/cnsatm2011/Briefs/01-Monday/08-Dreher-HBAJ%20WeatherOverview.pdf.

4. METOC Handbook; http://www.dtic.mil/doctrine/doctrine/jwfc/metoc_hbk.pdf.

KEYWORDS: tactical weather sensors, secure mobile applications, secure data transmission, Android OS, iOS, Kestrel, Air Force Weather, mobile device software, observation, forecast

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AF141-049 TITLE: Command and Control of Dynamic Traffic Prioritization (C2DTP) to Enable Mission-Responsive Crypto-Partitioned Networks

KEY TECHNOLOGY AREA(S): Battlespace Environments

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Provide commander the ability to reprioritize traffic dynamically within a crypto-partitioned network to maximize mission responsiveness to changing battlefield needs. C2DTP provides commander graphical geospatial control over communications nodes.

DESCRIPTION: Network traffic prioritization is traditionally controlled by creating policies on a network's routers. This process is difficult, requiring highly-skilled information technology and security specialists, and, even with expert construction, the policies are often error-prone and subject to revision to invoke new or modified policies as battle space conditions and higher headquarters decisions change. Moreover, networks with cipher-text (CT) cores significantly complicate matters as black-side routers cannot distinguish encapsulated packets based on their original contents.

The Air Force seeks a quality of service (QoS) solution that is capable of disseminating prioritization policies, which are based on commander's mission needs, over a CT core. The goal is to enable a network command authority to choose network traffic prioritization policies "on the fly" instead of being saddled with one-size-fits-all configurations for an entire mission.

If the network's routing core were not crypto-partitioned (CT core), command-defined traffic prioritization could be realized with existing network QoS mechanisms (e.g., IntServ, DiffServ, SWAN) or through minor enhancements of these existing QoS mechanisms. However, the need to determine the priority of both ends of the flow, adjust to the highest priority, and then convey this information from the plain text (PT) side endpoints to the CT core routers along the path, is a major technology gap that needs to be closed.

The proposed solution should preserve the strict separation rules of crypto-partitioned tactical networks, i.e., no information from the original packet is conveyed in plaintext across the CT core. It should operate in the traditional policy-based QoS mode, as it does today, until override is requested by the commander's communications team. Furthermore, the solution should not introduce additional out-of-order delivery of application-layer packets. The solution should support different classes of traffic (e.g., fire control, voice, video stream, Web, e-mail) and dynamic prioritization within the traffic classes.

Commercial Potential: Internet service providers could use such an approach to offer data prioritization to their customers who employ virtual private networking over the Internet.

PHASE I: Develop concept through analysis and simulation. Provide means to represent communications nodes graphically and geospatially, allowing communications leads (JICO, A3, A6, Cyber Control) means to rapid reconfigure routing schemes without manual commands to routers. Provide means to prevent introduction of errors and misrouting through positive control of operator authority and set conditions.

PHASE II: Construct prototype system of C2DTP with means to demonstrate manual routing control and a simple geospatial routing control with innovative user interface (use [NASA] WorldWind, NGA [DoD] GoogleEarth, AGI STK, AgileClient, or similar geospatial GUI in use by USAF). Demonstrate how RF propagation and performance parameters (e.g., distance, ERP, BER, etc.) and compatibility of routed RF nodes are accommodated.

PHASE III DUAL USE APPLICATIONS: Migrate concept to tactical airborne network efforts. Commercial Potential: Internet service providers could use such an approach to offer data prioritization to their customers who employ virtual private networking over the Internet.

REFERENCES:

1. IntServ: RFC 2215, "General Characterization Parameters for Integrated Service Network Elements."

2. DiffServ: RFC 2475, "An Architecture for Differentiated Services."

3. Gahng-Seop Ahn, Andrew T. Campbell, Andras Veres and Li-Hsiang Sun, "SWAN: Service Differentiation in Stateless Wireless Ad Hoc Networks," Proceedings of the 2002 IEEE INFOCOM, New York, NY, June 2002.

KEYWORDS: dynamic network control, Quality of Service (QoS), geospatial network management, SWAN, RFC-2215, RFC-2475, crypto-partition management

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AF141-052 This topic has been removed from the solicitation.

AF141-054 TITLE: Advanced Indexing and Search for Efficient Information Discovery

KEY TECHNOLOGY AREA(S): Information Systems Technology

OBJECTIVE: Research & develop an advanced indexing and search capability that combines Information Extraction and Information Retrieval methods to enable rapid identification & discovery of relevant information in large (web scale) volumes of textual data.

DESCRIPTION: Finding and extracting new knowledge from large volumes of textual data remains one of the most significant challenges to intelligence analysts. This problem spans across multiple intelligence domains (ex. Behavioral Influence, Command and Control), requiring systems to be adaptable in both a multi-domain and dynamic world environment. As the volume of data continues to grow beyond the capacity of intelligence analysts to cull through it, the need to identify relevant information in a timely manner further compounds the problem. Analysts need capabilities that support efficient identification and discovery of relevant information in web- scale document collections within a time-limited window of analysis.

Current tools for Information Retrieval (IR) are too general and current tools for Information Extraction (IE) are too specific to effectively meet the needs of intelligence analysts working in a continually changing environment. IR systems allow the analyst to cast a wide net when searching for information, do not require apriori knowledge of what the analyst will be looking for, and support serendipitous discovery of relevant information the analyst may not have known to look for. However, they fail to identify information in a narrower context and do not identify entities, events, and relations. IE systems, on the other hand, automatically identify entities, events, and relations and provide structured information from unstructured text. However, these systems must be customized apriori to the domains of interests, and the analyst is only able to find information that the system extracted.

The goal of this topic is to research and develop an advanced indexing and search capability that combines Information Retrieval (IR) and Information Extraction (IE) methods to: (1) dynamically model user information needs, including building models for retrieving entities, events, and relations; (2) rapidly search large (web scale) volumes of textual data to identify relevant information; (3) return relevant information with precision and recall which exceeds the current state-of-the-art; and (4) enable users to refine or change their information needs over time through interacting with the system. By combining IR and IE methods, and increasing user interaction with the system to model, persist, and refine their information needs, analysts will be better enabled to find a more complete set of relevant information from large volumes of textual data in a time- limited window of analysis than they would using IR or IE individually.

PHASE I: The goal of Phase I is to investigate advanced indexing and search capabilities that combine IE and IR methods to enable rapid identification and discovery of relevant information in large (web scale) volumes of textual documents. The investigation should produce a prototype design that considers multiple domains and entity, event, and relation types.

PHASE II: The goal of Phase II is to implement the Phase I design into a prototype system that can be demonstrated across multiple domains and entity, event and relation types. This phase would also include functional and performance testing of the prototype, and demonstration that the prototype meets the goals of this topic.

PHASE III DUAL USE APPLICATIONS: An advanced indexing and search application that combines IE and IR methods would benefit military intelligence analysts, as well as law enforcement and homeland security customers who need to rapidly identify relevant information in large volumes of textual data.

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KEYWORDS: indexing, search, information retrieval, information extraction, dynamic modeling, interactive retrieval, interactive extraction

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AF141-055 TITLE: Enhancing Real Time Situational Awareness with Latent Relationship Discovery

KEY TECHNOLOGY AREA(S): Information Systems Technology

OBJECTIVE: Provide improved real-time situational awareness through discovery of unknown relationships across multiple structured and unstructured textual data sources.

DESCRIPTION: The number of textual data sources, formats, and types available to information analysts has exploded in recent years. Often, the relevant data about an entity or event of interest is scattered across multiple data sources and is incomplete within a single data source. There is a need to discover previously unknown relationships pertaining to entities and events of interest across these multiple data sources in order to help analysts find more complete information about those entities and events. Such a capability would support tasks such as maintaining situational awareness, patterns of life analysis, and providing real time alert notifications to the analyst from multiple text-based intelligence data sources.

Current approaches to relationship extraction suffer from limitations of using contextual and syntactical cues, which are not scalable and have limited statistical reliability in identifying previously unknown relationships. By leveraging new developments in statistical relational learning, novel relationship discovery algorithms are emerging. The challenge in an operational environment is to provide situational awareness to the analyst in real time. This requires the development of incremental learning models that reduce the time complexity currently required. Basic algorithm work is needed to not only leverage the advances in statistical relational learning for relationship discovery, but to do so in an operational setting enabling online updates of models across multiple unstructured and structured data sources. This analytic operation would significantly increase the accuracy of reports or intelligence summaries that could be used to provide real-time alert notifications to the user.

The goal of this topic is to research and develop algorithms for discovering previously unknown relationships, pertaining to entities and events of interest, across multiple unstructured semi-structured and structured text-based intelligence data sources, mIRC, and various databases. The algorithms should be scalable and capable of operating in real time, in order to support both forensic and real-time use cases. Such a capability would enable intelligence analysts to efficiently leverage more sources of data for their tasks and enhance their situational awareness by providing more complete information than can be found in each data source alone or by manually identifying relationships across sources in a time-limited window of analysis.

Military Application: The higher order fusion of information is fundamental building capability to enhancing the output from today’s intelligence analysts. The techniques and algorithms developed can be applied to information centric systems to simplify the discovery of not just information but to detect broader relationships than possible today. Relationships can be identified based on holistic analysis of all available data to enable support of warfighters in an operational setting where improved situational awareness is crucial. The results of this research would also be useful to Department of Homeland Security's many databases, like that used to check passengers on various forms of traffic (such as airplanes, trains and ships).

Commercial Application: The development and products from this research endeavor can be applied to information centric systems that require the discovery of relations that can lead to unknown intelligence or knowledge. Examples of systems that would benefit would be FBI database scheme, and state and local police databases. The ability to discover relations in data would also be beneficial to banking and state motor vehicle agencies.

PHASE I: The goal of Phase I is to investigate scalable algorithms for discovering unknown relationships, pertaining to entities and events of interest, across multiple unstructured and structured textual data sources in real time. The investigation should produce a prototype design for relationship discovery across these sources. Developed capabilities will be demonstrated by use of open source data.

PHASE II: The goal of Phase II is to implement the Phase I design into a prototype system that can be demonstrated across multiple unstructured and structured textual data sources, in forensic and real-time scenarios. Unclassified and classified data will be provided for evaluation of developed research. The prototype system should be SOA-compliant to facilitate integration with other systems.

PHASE III DUAL USE APPLICATIONS: A capability for discovering unknown relationships across multiple data sources would benefit military intelligence analysts. It would also benefit customers, such as FBI, state/local police, and Department of Homeland Security, who leverage data found in multiple databases and unstructured sources.

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2. "Relationship Discovery in Large Text Collections Using Latent Semantic Indexing" by R. B. Bradford, SAIC, 2006 SIAM Conference on Data Mining Workshop on Link Analysis, Counterterrorism and Security.

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KEYWORDS: latent relationship extraction, structured data, unstructured data, entity, events, associations, anomalies, patterns, higher order logic

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AF141-056 TITLE: Early Design Analysis for Robust Cyberphysical Systems Engineering

KEY TECHNOLOGY AREA(S): Information Systems Technology

OBJECTIVE: Develop an innovative automated design/analysis framework establishing consistent use of MARTE with UML, SysML and other design notations to enable robust engineering through early performance analysis in development of distributed, real-time systems.

DESCRIPTION: Real Time Embedded Systems (RTES) are critical components of cyberphysical systems. Model Driven Engineering (MDE) is an approach to software development based on models and transformations among them that is emerging as a viable approach for RTES software and systems development. Models may be specified in OMG's Unified Modeling Language (UML), Systems Modeling Language (SysML), or other languages. However, languages like UML are too broadly defined to be used in performance analysis of cyberphysical systems. To address this concern, OMG creates profiles to restrict and define the modeling language to certain domains.

Modeling and Analysis of Real Time Embedded Systems (MARTE) is a profile associated with UML and SysML and supported by OMG. MARTE allows for both a design and an analysis model of RTES. The design model has a High Level Application Model (HLAM) package to explicitly represent the communication, coordination, and computation of RTES; a Generic Component Model (GCM) to represent components used in an RTES, and other packages. Designers are motivated to use these packages to explicitly represent behavior and to generate code to the maximum extent possible. MARTE is also key to performance assessment of UML/SysML designs for early design analysis. Reports demonstrate performance assessment with the Performance Analysis Model (PAM), and schedulability assessment with the Schedulability Analysis Model (SAM) [Espinoza 2007 and others].

While integrated design and analysis has been demonstrated to be viable, there are remaining difficulties in automating those assessments. Automation of performance assessment is possible in a restricted domain [Moreno and Smith 2009], but automating the assessment for any design in any domain faces significant challenges. One of the key challenges is in the integration of models commonly used for system production or software code generation with the information that is relevant to perform analysis. Integration is essential for accuracy and consistency of the models [Espinoza et.al. 2009]. Creating performance specifications with PAM requires considerable expertise in performance analysis which limits the ability to automate the performance analysis for designers. Espinoza et.al. report another challenge is that there are multiple ways to express the same design feature in MARTE and SysML and there is "not a predetermined approach to use the (MARTE with SysML) language constructs through the development life cycle." Not only are there multiple notations that may be used, there are multiple ways of "overlaying" MARTE specifications on the design model. They may be on multiple diagrams such as sequence diagrams, activity diagrams, deployment diagrams, etc.; they may be spread through several diagrams; and there may be multiple stereotypes on a single element. There are also tool differences in how these specifications are represented in an XML (Extensible Markup Language) Metadata Interchange (XMI) file.

One such approach is to create a domain-specific modeling language that uses a merged meta-model of only the features needed, along with possible extensions to represent missing features for that domain [Quadri 2010]. This is a powerful technique, however optimally suited for a restricted domain that lends itself to automation and is useful for proof of concept demonstrations. It is undesirable, however, to have many such languages that each require special industrial-strength tool support, and integrating various parts of the design in different languages to represent all aspects of a large-scale system is especially problematic [Espinoza et.al. 2009].

PHASE I: Define and architect an automated design and analysis framework establishing consistent use of MARTE with UML, SysML, and other design notations and enabling robust systems engineering through early performance analysis. Appropriate analysis techniques need to be selected and the conceptual approach and design of how to integrate the technologies be completed.

PHASE II: Develop, implement, demonstrate and validate the concepts and design created during Phase I. Tools and interface approaches would need to be selected, integrated and/or developed. Demonstration of the solution's openness, scalability, and degree of automation in the exchange of design data should be performed, as well as accomplishing performance or real-time analysis against a representative DoD design.

PHASE III DUAL USE APPLICATIONS: Military application: This work would be applicable to any DoD system that has distributed and/or real-time characteristics. Commercial application: The telecom, automobile, and manufacturing and control industries in general experience the same issues and would find this technology useful.

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4. [OMG 2003] Object Management Group, “MDA Guide,” Version 1.0.1 OMG/03-06-01, June, 2003.

5. [OMG 2007] OMG. 2007. Modeling and Analysis of Real-Time and EmbeddedSystems (MARTE). http://www.omgmarte.org/.

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KEYWORDS: Automated Design and Analysis Framework, System Performance Modeling, Robust Systems Engineering, Model Driven Engineering, Real-Time Cyberphysical Systems modeling, Modeling and Analysis of Real Time Embedded Systems, MARTE

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AF141-057 TITLE: Living Plan

KEY TECHNOLOGY AREA(S): Information Systems Technology

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Keep military plans alive by developing innovative ways of dynamically maintaining efficacy of military plans at the strategic, operational, and battle planning levels, as things change (i.e., keep plans current; keep plans executable).

DESCRIPTION: We are looking for revolutionary ideas on how to enable the conduct of well-coordinated, synchronized military operations among all available military forces to achieve unities of effort. At the heart of such integrated Command and Control (C2) capabilities is the ability to plan and task assets across federated war-fighting domains (horizontally and vertically). The complexity of such integration, need for high-speed decisions, and the exceptionally rapid change in world state drives the need for highly adaptable, constantly updating plans (i.e., living plans). Hence, this topic is asking for ways and means of sustaining plans at any and/or all levels of command.

The Adaptive Planning Roadmap II, signed by the Secretary of Defense on March 5, 2008, defines a living plan as, “A plan that is maintained continuously within a collaborative environment to reflect changes in guidance or the strategic environment. Automatic triggers linked to authoritative [data] sources, assumptions, and key capabilities will alert leaders and planners to changes in critical conditions that warrant a reevaluation of a plan’s continuing relevancy, feasibility, sufficiency, and risk. Living plans provide a solid foundation for transition to crisis action planning. Hence, contingency plans are no longer maintained on a cyclical basis but rather in a ‘living’ state (i.e., being refined and adapted as required) until terminated or handed over to crisis action planners for execution.” Two critical enablers of the “living” plan concept are dynamic apportionment and the ability of the Joint force provider to assess the availability and readiness of a plan's required assets. The living plan concept also extends down to battle planning and even battle management.

C2 planning systems at all echelons, therefore, must be able to reason over dynamic environments and to continuously update plans by synergizing the strengths, dependencies and relationships among the Joint forces brought to bear.

Some of the anticipated capabilities needed to enable the living plan concept are to continuously:
1) Represent and work with complex, nested structures like entities, capabilities, goals/objectives/intent, activities, sub-plans, processes, and plan branches.

2) Manage a changing set of partial plans, each composed of connected tasks (the further out, the more abstract) with their own timelines (hours to years).

3) Update based on near-real-time identification of changes to key planning assumptions and factors, while minimizing perturbations to other on-going mission threads and keeping federated activities synchronized.

4) Defer resource commitments as late as possible to achieve optimal operational execution.

5) Share/merge federated plans and operational pictures (i.e., world state) across the Global Information Grid via federated Service Oriented operations.

6) Task (re-task) on the fly.

Very simplistic, concrete examples:
- A contingency plan (e.g., OPLAN Aa) is being sustained to enable military forces to quickly react to a crisis in a given region of the world. OPLAN Bb covers a different region. Both have Unit XY standing ready to deploy. OPLAN Bb is executed and hence Unit XY is tasked. The C2 system automatically triggers an alert that OPLAN Aa needs a different unit assigned to fill in for Unit XY (i.e., keep plans on the virtual shelf from getting stale/unexecutable).

- A battle plan is being executed and a strike fighter is shot down. The C2 system automatically triggers alerts and highlights what objectives/effects are at risk of not being achieved and what options are available to fix the problem.

PHASE I: Conduct research, glean knowledge from subject matter experts, develop relevant military use cases to validate concepts, and design revolutionary ways of keeping plans current.

PHASE II: Develop, demonstrate, and validate a prototype in a relevant scenario clearly demonstrating ability to meet the desired capabilities and defined metrics within a service oriented environment.

PHASE III DUAL USE APPLICATIONS: The novel capabilities developed will be useful in all C2 applications that involve the planning of events whether they are military (e.g., attack, air refueling, surveillance) or commercial (e.g., homeland security, sporting events, transportation, and agriculture).

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4. Adaptive Planning Roadmap II, signed by SecDef on 5 MAR 2008.

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KEYWORDS: Command and Control, Living Plan, OPLAN, adaptive military planning, C2, unities of effort, Adaptive Planning

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AF141-058 TITLE: Architecture for Enterprise Anonymization

KEY TECHNOLOGY AREA(S): Information Systems Technology

OBJECTIVE: Develop innovative methods for ensuring privacy and operations security (OPSEC) for individual users across an enterprise while searching, browsing or chatting on the Web.

DESCRIPTION: Consider the following scenario: An important meeting is held at an Air Force organization. Immediately afterward there is a spike in web searches coming from that organization. Identification of the topic and impact of that meeting will be a trivial thing for a search provider. Spikes in web traffic are regularly evaluated by search providers to identify trends or to give users more "personalized" search results. What else this data is (or could be) used for is left up to the imagination. In addition to search provider concerns, data aggregators also exist who work with many partners to discern a user's Internet activity.

In recent years the traditional threats to our industrial and military security have largely been replaced with the ubiquitous threats that come through the Internet. Physical and communications security is still important but the Web is an open channel for monitoring our organization's interest and activities. This is also a threat that we do not know how to close or even minimize for rank-and-file members of large enterprises.

In the Department of Defense, the need for privacy is embodied in our OPSEC program. The purpose of OPSEC is to identify critical information and analyze our actions with the intent to deny adversaries any indications of our operations and activities. In private industry, a similar concern is that of industrial espionage. Back as far as 1998, there was an estimate of $300 billion a year in potential loss to corporate America from theft of intellectual property.

Current methods available to anonymize our Internet traffic fall far short of that which would be required to truly protect us. The Tor routing service provides a big step in this direction but, for enterprise use, there are issues with speed, scalability and concerns about loss of anonymity at entry and exit nodes. Tor also does not address machine fingerprinting, browser history analysis, cookies and auto fill data hijacking. Proxy servers can change the IP address of the specific user but the proxy rarely will cover the identity of the organization that this person belongs to. Even when networking parameters are completely obfuscated, the traffic is still subject to fingerprinting techniques that can identify a specific machine or user.

This effort will develop architectures for privacy and OPSEC that will anonymize Internet search and browsing such that actions cannot be attributed to either an individual or organization. The solution shall be scalable across entire enterprises consisting of 1,000 or more client machines. It shall disrupt machine fingerprinting methods, all types of cookies, browser history analysis, form auto fill data hijacking, online behavior fingerprinting and network layer identity clues. The architecture can include a combination of currently available tools and appliances and/or new software, routing protocols or policy. The solution shall not rely on an outside entity to scrub our traffic since this would reveal our raw traffic to that entity. A demonstration of the technology shall be done such that the feasibility of this architecture for enterprise privacy/OPSEC can be verified.

PHASE I: 1) Design notional architecture(s) for privacy and OPSEC during Internet search, browsing and chat that is scalable across a large enterprise. 2) Define alternate methods or components where diversity may provide a more robust solution. 3) Proof-of-feasibility demonstration of key enabling concepts.

PHASE II: 1) Develop and demonstrate a prototype that implements the Phase I methodology, 2) identify appropriate performance metrics for evaluation, and 3) detail the plan for the Phase III effort.

PHASE III DUAL USE APPLICATIONS: MILITARY USE: OPSEC for DoD and other government enterprises during Internet search and browsing requires innovative methods and a robust, scalable solution. COMMERCIAL USE: Successful private architectures should be readily adopted by industry concerned with industrial espionage.

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1. DOD 5205.02-M DOD Operations Security (OPSEC) Program Manual Nov 2008.

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3. American Society for Industrial Security Report on Industrial Espionage, 1999.

4. DOD 5220.22-M National Industrial Security Program Operating Manual, Feb 2006.

KEYWORDS: anonymity, OPSEC, privacy, enterprise, scalable, architecture, anonymization, anonymizing

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AF141-062 TITLE: Lightweight Electric Wires and Cables for Airborne Platforms and Battlefield Air Force Personnel

KEY TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Develop an electrical conductor that is lighter and has two- to three-times higher electrical conductivity per weight than comparably rated copper (Cu) or aluminum (Al) wires.

DESCRIPTION: Electric wires and cables constitute by far the largest weight portion of aircraft electrical power systems, as well as a large fraction of an entire aircraft weight. Replacing Cu or Al wires with conductors that are substantially lighter would improve the fuel economy of an aircraft while also increasing the amount of useful load it could carry. In addition, the Battlefield Air Operations Kit (BAO) program has two documented requirements (both of them Key System Attributes) to reduce the weight and volume of electrical power management, which includes cables, in order to reduce personnel fatigue and snag hazards during special operations missions.

Due to reliance on traditional copper-wire cables, reducing the weight of electrical wiring systems has been elusive. However, recent development of conductors operating at ambient room temperature (72ºF) or extreme battlefield conditions of -30 to 125ºF, have shown promise to be much lighter than Cu or Al. For instance, iodine-doped carbon nanotubes (CNT) have been made into long length fiber strands that have about 300 and 50 percent higher electrical conductivity per weight than Cu and Al, respectively [3]. Composite multilayer structures of graphene + $FeCl_3$ made by intercalation were observed to have about two-times higher electrical conductivity per weight than Cu [4]. Other new approaches might include bulk assembly of metal nanowires, or < 1 micron-size topological insulator wires such as silicon-nanotubes with ultrahigh conductivity modes on the conductor surfaces [5].

Intercalating ultralight or porous materials into graphene or silicene base materials could further increase the specific electrical conductivity, and new nanoscale composite structures might be possible. CNT's and Si-nanotubes have low density (< 2.0 g/cm3) which is more than 4 times lighter than Cu (8.96 g/cm3), and can provide an excellent base for lightweight wire conductors. In addition, they have other useful properties as conductors, including high strength, pliability, and very low alternating current (ac) loss characteristics at low and high frequencies because of filament size < 1 micron.

It is essential that the specific electrical conductivity (conductivity/mass) of the new wires be greater than that of Cu or Al wires rated for the same current, within the desired operating temperature range. Successful concepts must ensure that wires are reliable and rugged enough for challenging environments and issues from prolonged use such as corrosion, wear and tear caused by chafing, wire fatigue, vibrations, rough handling, and other factors. Safety/health issues such as arc fires during failure are also important. Also volume density must be considered, as a non-traditional wire could be lighter with equal resistivity but have larger diameter or cross section compared to Cu, which can increase the electrical insulation coating weight and support structures on aircraft such as conduit housings. For this topic, wire conductors <= 20 A are of interest, that are typical for battlefield airmen and smaller aircraft such as group 2-4 small unmanned aircraft systems (SUAS).

Demonstrate feasibility to deliver wire products with the best combined properties for Air Force (AF) applications. Properties of interest include mass-specific electrical conductivity, flexibility, mechanical strength, conductor stability over time, wire fatigue, maintainability, and affordable life-cycle acquisition cost for present or eventual prototype-scale manufacturing.

PHASE I: Using lab-scale processes, make samples of novel conductors <= 20 A and length at least 10 cm length that have higher mass-specific electrical conductivity than Cu or Al wire. Develop suitable metric and methods of measurements for reliable and objective comparison of the novel conductors to standard metal conductors (Cu, Al). At Phase I end, present results at WPAFB.

PHASE II: Design and fabricate prototype-scale equipment for long-length conductor manufacturing, and provide deliverables of conductors 1-10 meters long rated for current in the range <=20 Amps. Evaluate properties such as mechanical, uniformity as a function of length, fatigue and time-stability of such conductors, and determine whether they can meet military specifications. Provide a cost benefit analysis for a specific AF system of interest such as BAO Kit or SUAS. Present results at WPAFB.

PHASE III DUAL USE APPLICATIONS: A multitude of aerospace vehicles will benefit from reliable light-weight conductors that will improve fuel efficiency and increase payload capability. Other potential civilian users include law enforcement, rescue crews, and others who typically have to carry electronic equipment to do their jobs.

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KEYWORDS: mobile electronics, wearable electronics, battlefield air operations, lightweight electrical conductor, mass specific electrical conductivity, carbon nanotube, silicon nanotube, carbon fiber composites, metal composite, graphene, graphene multilayer composite, highly oriented pyrolytic graphite, topological insulator, electrical power systems, power transmission wires and cables

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AF141-063 TITLE: Modeling the Impact of Silica Particle Ingestion on Turbomachinery Life

KEY TECHNOLOGY AREA(S): Materials / Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop a decision support tool to determine the impact of silica particle ingestion on component service life of the engine hot section.

DESCRIPTION: Operational requirements of commercial and military aircraft often render the traditional method of total avoidance of silica-rich particle contaminate ingestion infeasible. The 2010 Iceland volcanic ash cloud was of such a large extent that military sorties had to be rerouted around the outer perimeters of the cloud. Many airports around the world are subject to long-term exposure to sand-laden air. Also, volcanic clouds containing silica can be encountered in-flight before detection, resulting in inadvertent engine exposure. The current total avoidance strategy is driven by lack of detailed knowledge of how the two common particle types, fine sand and volcanic ash, affect engine components through several mechanisms of damage. These include erosive wear from mechanical action, impact damage from hard particles, contamination of accessories systems, and accumulation from melting and subsequent deposition within the hotter gas turbine engine components. Catastrophic failure of turbomachinery from high levels (approximately 0.1 gm dust per cubic meter of air) of calcium-magnesium-aluminum-silicon oxide (CMAS) particulates has been documented, but the effect of shortened component life imposed by reduced particulate loads that allow continued engine operation (approximately 1 µg to 1 mg per cubic meter), is not well understood. Glass accumulation on the combustor and turbine components may be an event that does not mandate replacement if thermal cycling allows thermal spallation of the glass accumulated; however, this may compromise component life. Compounding the problem is the widespread use of thermal barrier coatings in the turbine and combustor sections of advanced engines, where CMAS-induced coating loss can increase the risk of thermal fatigue in the base materials. Since sand and volcanic ash composition vary widely with geographic location, a tailorable CMAS particulate may be worth deriving for experimental approaches. The various minor chemical components in the CMAS can alter the phase change temperature of the silica, as well as serve as fluxing agents. It will be necessary to determine the depositional locations as well as the combined effects of some of the anticipated component life-reduction mechanisms, including degradation of the thermal barrier coating (TBC) layers, blade harmonic loading, and cooling boundary layers. This topic seeks a novel method of accounting for the cumulative exposure effects of silica-particulate containments upon turbomachinery components in regards to time change interval reduction from the phase-change deposition of the particulates. An expert-system and/or decision support tool that allows for reduction of operable time for various stages based on particulate size, concentration, and exposure time is a desired deliverable product. Phase I shall focus on the experimental design concept and numerical modeling tools that will use the experimental results to build a service life estimation tool that will downgrade the remaining service life based on CMAS accumulation, cooling disruption, thermal barrier erosion and other compromised conditions. Phase II will involve testing components that have had CMAS accumulated on them, validating the numerical extrapolation model against them to generalize the change in loading as a function of CMAS time and concentration exposure. Based on the outcomes of this test effort, a validated fatigue-failure numerical model will be used to determine remaining service life as a function of CMAS exposure levels.

PHASE I: Demonstrate the feasibility of simulating glass accumulation effects on components at various conditions within gas turbines. Demonstrate CMAS formulations for representative sand and volcanic ash systems. Show a modeling concept that can be validated against test conditions and allows a generalized component time change modification model to be generated. Develop a test plan for this purpose.

PHASE II: Demonstrate testing for glass accumulation effects of CMAS particulates at various engine operating conditions (temperature, species, velocity, concentration, and size parameters). Validate the modeling concept against test data from demonstration cases in collaboration with government and industry end users. Deliver a decision support tool that adjusts time change interval of components based on silica particulate exposure history and engine conditions, and an instruction manual for tool use.

PHASE III DUAL USE APPLICATIONS: Adoption of the tool by aircraft maintenance organizations will support dispositions for exposed engines. Commercial benefits include improved opportunities for providers of air services to refine risk when operating in environments with pervasive silica-particulate contamination.

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4. Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds, Doc 9691 AN/954, International Civil Aviation Organization, Second Edition, 2007.

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KEYWORDS: decision support, service life modification, trade space, particulate contamination, gas turbine, maintenance disposition, volcanic ash, sand ingestion, glass

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AF141-064 TITLE: Additive Metal Manufacturing (AMM) Process Development for Gas Turbine Engine Component Repair

KEY TECHNOLOGY AREA(S): Materials/Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop and validate an additive-metal manufacturing repair process for complex engine components in aging Air Force (AF) fleets.

DESCRIPTION: Gas turbine engine components experience damages such as fatigue, foreign object damage (FOD), erosion, and fretting wear that make the sustainment of fleets burdensome. Damaged components in most AF fleets are usually replaced with new parts supported by the original equipment manufacturer (OEM); however, the AF still owns and operates a number of aging engines no longer supported by OEMs. Though some of the unsupported components were manufactured from known, commercially available materials, some were made from either proprietary or unavailable material compositions with sometimes unknown manufacturing processes and parameters. In order to sustain aging fleets and unsupported components, an additive metal manufacturing (AMM) and re-engineering effort for part repair and remanufacturing is being explored. The primary manufacturing procedure for this effort is direct metal laser sintering (DMLS). This procedure requires both test validation and equipment enhancement to qualify the AMM repair and remanufacturing capability for flight components.

Validating the remanufacturing or repair of unsupported engine parts requires adherence to the Federal Aviation Administration (FAA) part manufacturing approval (PMA) process. The FAA states that two basic ways that a PMA applicant can show that a part meets airworthiness standards are as follows: first, establish identicality between the remanufactured or repaired and certified parts, and second, show through tests and computations that the remanufactured or repaired part meets airworthiness requirements. In the case of identicality, it must be shown that the remanufactured or repaired part is identical in material composition and functionality to the original part via mechanical material property performance. As for test and computation, the remanufactured or repaired part must show similarities in airworthiness functionality to the original part, only; meaning, the identicality of the functionality and the material composition is not of great importance.

The innovative research required to attain airworthiness and to meet the standard for AMM repair is as follows: for Phase I, develop a DMLS repair process for blended/cutout aluminum and titanium coupon specimens and validate functionality by comparing failure results of repaired and baseline (pristine) coupon specimens; for Phase II, validate the DMLS repair process for an aluminum alloy with the same functionality as the TF33 fuel pump housing and conduct the repair on the part. Material property data for TF33 will be provided by the AF. Phase II may also require an enhancement to the equipment used for DMLS repair, specifically software control and powder application, so that repairs can be made on components with geometries that are more complex than that of coupon specimens. A final presentation of the repair capability demonstrated in the Phase II activity is required at Wright-Patterson Air Force Base.

To successfully perform the work described in this topic area, offerors may request to utilize unique facilities/equipment in the possession of the U.S. Government located onsite at Wright-Patterson Air Force Base. Accordingly, the following items of Base Support may be provided to the successful offeror, subject to availability and negotiations, in accordance with the clause in Air Force Materiel Command FAR Supplement (AFMCFARS) 5352.245-9004 “Base Support.” The facilities/equipment include the Turbine Engine Fatigue Facility (TEFF) and certain fracture, fatigue, and vibration testing and measurement systems therein.

PHASE I: Validate high and low strain rate material strengths [1,2], fatigue crack growth [3], low cycle and high cycle fatigue rates [4,5] of DMLS-repaired aluminum and titanium coupon specimens via comparative experimental study against respective baseline specimens. Demonstrate repair capability on coupon specimens by showing functionality within 20 percent when compared to baseline results.

PHASE II: Determine material properties of the TF33 fuel pump housing and gear wipe (AFRL), conduct Phase I activities on housing and gear wipe materials, and conduct successful repair of housing and gear wipe. Deliverables: a FAA PMA validated repair capability for TF33 housing and gear wipe.

PHASE III DUAL USE APPLICATIONS: Military: AMM repair used to reduce sustainment costs, including part purchasing, and the design and fabrication of obsolete parts. Commercial: AMM repair is adopted by OEMs or a nonaerospace consumer--the former for solidifying customer satisfaction, and the latter to reduce part replacement costs.

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1. American Society for Testing and Materials, “E 8 - 09: Standard Test Methods for Tension Testing of Metallic Materials,” ASTM Book of Standards, 2009; Vol. 03.01, ASTM International, West Conshohocken, PA.

2. T. Nicholas, "Tensile Testing of Materials at High Rates of Strain," Exp. Mech. 21 (1981) pp. 177-188.

3. American Society for Testing and Materials, “E 647 - 08: Standard Test Method for Measurement of Fatigue Crack Growth Rates,” ASTM Book of Standards, 2008; Vol. 03.01, ASTM International, West Conshohocken, PA.

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KEYWORDS: sustainment, repair, additive metal manufacturing, DMLS, aluminum, TF33 fuel pump

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AF141-065 TITLE: Structural Health Monitoring (SHM) Methods for Aircraft Structural Integrity

KEY TECHNOLOGY AREA(S): Air Platforms

OBJECTIVE: Develop fuse-like SHM techniques for the ASIP environment. Methods must be reliable, low cost, and durable. Methods must reduce maintenance burden, while maintaining safety.

DESCRIPTION: The U.S. Air Force utilizes a damage-tolerant design approach to ensure the structural safety and reliability of the airframes on its fleet. A critical facet of this damage-tolerant design approach is nondestructive inspection (NDI). These inspections ensure that a critical crack is not present in the inspected region and that any defects present are so sufficiently small that they will not grow to failure during the next service interval. While this approach is effective, the maintenance burden associated with repeated inspections can be problematic. The inspections themselves can be difficult and significant disassembly of the structure may be required to gain access to the inspection areas. Since there are typically many inspection points on an aircraft, this can result in significant cost and downtime for the aircraft.

Unconventional approaches to supplement these aircraft structural inspections in an ASIP environment are desired. This effort will focus on developing a fuse-like system that will be implemented in the area where cracking is anticipated to occur on a metallic structure. These mechanical fuses may be bonded or utilize a direct-write methodology in which the sensor traces are directly deposited in the surface of the structure. Once the crack initiates and starts to propagate through the region where the sensors have been attached, the sensor traces will break, thus giving the indication of damage. The developed fuse system should be able to detect cracking of 0.1 inch or better. Remote determination functionality must permit indications of initiation and size of damage, either through a strategically located data port or wirelessly transmitted to a hand-held device. The developed sensor technology must be suitable for robust operation in the austere flight/field environments with limited maintenance and low false call rates as well as high detection capability.

In Phase I, demonstrate the developed fuse-type SHM approaches for aircraft structural integrity to provide a proof-of-concept model or prototype that is scalable to a full-size aerospace structure. Crack initiation and sizing will be demonstrated on a simple metallic, laboratory dogbone specimen. Demonstrate that the approach causes no degradation in the underlying specimen. Provide the ability to perform sensor health checks to differentiate between a damaged sensor or a damaged structure. Outline a viable validation path to ensure compliance with MIL-HDBK-1530C (ASIP) or a logical evolution thereof.

In Phase II, develop and conclusively demonstrate a prototype application of the developed approaches and validate the reliability of such a device in a relevant environment. It is recommended to partner with a potential end user of the technology to maximize the relevance of the demonstration and facilitate subsequent transition/commercialization. The demonstration of the developed system should show that the system is applicable to a more realistic aircraft structure with significantly more complicated geometry. Demonstrate that the developed technique can achieve a high probability of detection rate and low probability of false alarms. Examine the possibility of moving from accessing the data via a strategically located data port to the use of a hand-held device where the data could be wirelessly transmitted.

PHASE I: Demonstrate fuse-type SHM methods for aircraft structure to prove scalability. Crack detection and sizing will be demonstrated on metallic laboratory specimens. Demonstrate that the approach causes no negative impacts. Sensors must differentiate between damaged sensors and damaged structure. Outline a viable path to ensure compliance with MIL-HDBK-1530C.

PHASE II: Develop and demonstrate a prototype application and demonstrate the reliability of the device in a relevant aircraft environment. Recommend partnering with a potential end user to maximize the relevance and facilitate subsequent transition. The demonstration should show that the system is applicable to realistic aircraft structures with complicated geometry. Demonstrate high probability of detection (0.1 inch or better) and low probability of false alarms.

PHASE III DUAL USE APPLICATIONS: The developed fuse-type SHM system would be fielded for relevant U.S. Air Force applications and fielded into broader commercial markets.

REFERENCES:
1. MIL-HDBK-1530C, General Guidelines for Aircraft Structural Integrity Program (ASIP).

2. Air Vehicle Integration and Technology Research (AVIATR) Delivery Order 0002: "Condition Based Maintenance Plus Structural Integrity (CBM + SI) Strategy Development," Final Report, Nov 2010, DTIC Number ADA546937.

3. Air Force Institute of Technology, Thesis for Master of Science in Systems Engineering, "An Enhanced Fuselage Ultrasound Inspection Approach for Integrated Structural Health Monitoring Purposes," Mar 2012.

KEYWORDS: health monitoring, structural integrity, nondestructive inspection, damage tolerant design, lifecycle management, aircraft availability, total ownership cost

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AF141-066 TITLE: Use more accurate aircraft usage data in predicting life and scheduling inspections

KEY TECHNOLOGY AREA(S): Air Platforms

OBJECTIVE: Obtain a more accurate prediction of remaining life and inspection interval for an individual aircraft by converting actual aircraft usage data into stresses on the structure via physics-based, real-time aeroservoelastic simulations.

DESCRIPTION: The process of determining initial or remaining aircraft structure life has not significantly changed in 50 years. It is still a highly manual and labor intensive process, individual steps are not easily integrated together, and the advantages of high performance computing have not been fully utilized. Recently, the Air Force Research Laboratory has produced a long-term vision, called Airframe Digital Twin (Ref 1), that is beginning to address these issues. This project will be one of the crucial early steps toward the Airframe Digital Twin vision.

Several U.S. military aircraft (e.g., F-16, F-15, C-5, and A-10) are reaching or are already beyond their originally designed, fatigue lives. To identify their residual fatigue life or extend their fatigue life by retrofit, accurate loads spectra to perform fatigue analyses or ground fatigue tests on these aircraft is required. Physics-based models of crack formation and growth are also required, since empirical models based on a large database of historical crack formation and growth are helpful in detecting cracks, but lack understanding of, and insight to, the physics of how cracks are formed.

Aircraft life prediction and inspection intervals have traditionally been generated using empirical models applied to a single, standard aircraft usage profile for the entire fleet. These models are expensive to generate and update. The transition from event-based to real-time flight data recorders on individual fleet members provides Aircraft Structural Integrity Program (ASIP) managers with powerful new information to transition to individual life predictions and inspection intervals. However, ASIP managers currently lack a toolset and process to re-evaluate life and inspection intervals for an individual aircraft, flown by a unique pilot, carrying a particular payload configuration, and burning fuel throughout.

This toolset and process should receive the recorded flight data (e.g., aircraft states, control surface deflections, fuel level, stores configuration) as inputs. The real-time aeroservoelastic simulation must be physics based, and capable of incorporating variation in pilot, vehicle mass/inertia, manufacture, and repair history. The process should produce an updated life prediction and inspection interval based on damage tolerance analysis which utilizes the more realistic and accurate dynamic loadings obtained from simulation.

PHASE I: Demonstrate feasibility for quantifying variation in dynamic loads due to changes in vehicle inertial properties from mission to mission. The dynamic loads include both 1) surface pressures on the air vehicle and 2) big bone/component loads such as wing root bending. This task can be accomplished with a finite element model and an aerodynamics model derived from an outer moldline.

PHASE II: Integrate the dynamic loads variational capability developed in Phase I into a relevant 6-degrees of freedom (DOF)-vehicle simulation environment. Identify critical maneuvers/flight conditions via enhanced 6-DOF simulation and application of the resulting loads spectra to the air vehicle finite element model (AV FEM). Identify critical stress regions (hot spots) within the AV FEM. Establish correlation between these global hot spots and an individual structural component damage tolerance model.

PHASE III DUAL USE APPLICATIONS: The resulting capability has applications in both 1) prototype development activities and 2) service life extension programs.

REFERENCES:
1. Eric J. Tuegel, Anthony R. Ingraffea, Thomas G. Eason, and S. Michael Spottswood, "Reengineering Aircraft Structural Life Prediction Using a Digital Twin, "*International Journal of Aerospace Engineering*, Vol. 2011.

2. P.C. Chen, D.H. Baldelli, and J. Zeng, "Dynamic flight simulation (DFS) tool for nonlinear flight dynamic simulation including aeroelastic effects," in *Proceedings of the AIAA Atmospheric Flight Mechanics Conference and Exhibit*, Honolulu, Hawaii, USA, 2008, AIAA 2008-6376.

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KEYWORDS: aircraft life prediction, aircraft usage, aircraft structural integrity program, structural dynamics, aircraft aging, aircraft loads, fatigue life, recorded flight data

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AF141-067 TITLE: Structural Reliability Analysis

KEY TECHNOLOGY AREA(S): Air Platforms

OBJECTIVE: The objective is to develop a structural reliability analysis calculation tool that has the capability and flexibility to correctly model the physics of the variety of possible post-inspection structural repair options.

DESCRIPTION: The current structural reliability analysis software used by the USAF models the post-inspection condition of the structure as a repair crack size distribution only. Such a model for a post-inspection repair is adequate if the repair is oversizing a fastener hole up to the second oversize. But if the repair is a doubler, or an interference fit bushing, the repair crack size distribution cannot capture the changes in the crack growth curve or maximum stresses in the part. A structural reliability analysis tool is needed that has multiple options for changing the reliability calculation inputs after an inspection. Since the type of repair performed is dependent upon the size of the crack found during the inspection, more than a single repair model is required. Furthermore, because the repair options for different airframe locations are different, the models for repairs and when they are applied needs to be flexible so that the reliability analyst can select which models to use and when they are applied. Repairs to be considered are oversizing of fastener holes and patches at a minimum.

Object-oriented modeling software, like ModelCenter or SPISE, for example, have created modeling environments in which it is possible to construct a flexible engineering analysis tool. Basic function routines can be created as modules. These modules have specified inputs and outputs. They form the building blocks for constructing an engineering model. These modules are linked together in different ways and are used over and over again in building the model.

While it seems that structural reliability analysis would lend itself to models constructed in one of these object-oriented environments, it is not clear how this can be done. The fundamental routines for structural reliability analysis need to be determined and developed into modules. Examples of two modules needed, based on routines in the current reliability analysis tools, are probability of crack detection during nondestructive inspections (NDIs) and probability of failure. The framework for how these modules should be linked together in order to perform a structural reliability analysis needs to be developed. Finally, the flexibility of this framework needs to be demonstrated for a number of different structural components. The intent of this project is not to develop an object-oriented modeling environment. It is rather to build a structural reliability analysis framework within a commercial off-the-shelf (COTS) object-oriented modeling environment. This framework must have the flexibility to accommodate the variety of possible repair scenarios and their effect on the random variables in a structural reliability analysis of fatigue in metallic structures: fracture toughness, crack size, and maximum stress during a flight.

PHASE I: Phase I will develop the basic routines needed for structural reliability analysis into reusable modules for a particular object-oriented modeling environment. These modules will be demonstrated by simulating reliability analysis for the lifetime of a single structural component.

PHASE II: Phase II will develop the ability to statistically update the prior reliability analysis for a location based upon new information such as the size of any cracks found during inspections or what repair was actually performed. This capability will be demonstrated by performing reliability analyses over the lifetime of multiple different structural components. The demonstration will take place at WPAFB. A manual describing how to use the software will be required.

PHASE III DUAL USE APPLICATIONS: Phase III applications of this reliability analysis technology include all USAF aircraft systems. Application to Army, Navy, and commercial aircraft is possible, but will require that some additional modules be developed since each organization has slightly different requirements.

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1. Berens, A.P., Hovey, P.W., and Skinn, D.A., "Risk Analysis for Aging Aircraft Fleets," WL-TR-91-3066, DTIC #ADA252000, 1991.

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3. SPISE software, http://www.predictionprobe.com/index.php/site/products/spise/.

4. Tuegel, Eric, Modeling Repairs in Structural Rick & Reliability Assessments, ASIP Conference, Bonita Springs, FL, 3 Dec 2013, 26 pages, uploaded in SITIS 12/9/13.

KEYWORDS: structural reliability, probability, object-oriented modeling, reliability of repairable items, repair quality models

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AF141-068 TITLE: Generic Power/Propulsion Microcontroller for Unmanned Aircraft Systems (UAS)

KEY TECHNOLOGY AREA(S): Air Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop and demonstrate a small, common controller that can efficiently control all aspects of propulsion and power management for UAS vehicles.

DESCRIPTION: The use of UASs has greatly increased over the last 12 years and these systems are assuming greater operational roles in the field, becoming force multipliers for the military. Current controls for UAS propulsion, especially small UASs, typically are simple throttle actuators. The next-generation UAS power/propulsion systems will require state-of-the-art controls to manage systems for peak performance. Next-generation propulsion and power systems are being developed to take advantage of technology development in lightweight, efficient electric propulsion, high-density power storage, advanced internal combustion (IC) and turbine concepts, and electrical systems. Technologies under development such as microfuel injection, microfuel pumps, micro-ignition systems and microturbochargers are being integrated into UAS power/propulsion systems. A combination of software and hardware will be needed to manage performance functions of the power/propulsion system. A controller is desired that can be applied to the power/propulsion system, regardless of the approach, seamlessly switching or connecting diverse propulsion modes and electrical sources with different torque, voltage, current, and impedance characteristics as needed and if needed. Concepts proposed should provide the ability to be incorporated as a hierarchical software component of the vehicle electric power, propulsion, and flight control. It is important to evaluate methodologies that enable parameter monitoring capability, system transients, and potential failure modes. Proposals must demonstrate a grasp of UAS controls issues and needs. Concepts should be well defined for both their hardware and software visions. Cost, flexibility, growth and other issues not articulated here are all capabilities that need to be explored.

PHASE I: Demonstrate the feasibility of small control systems that can handle the real-time operation of potentially complex power/propulsion systems for UAS platforms. Evaluate the potential to develop a system that handles all mission modes efficiently while minimizing transient responses, especially in flight modes.

PHASE II: Develop and refine the Phase I concept into a hardware and software prototype system. Demonstrate the system capability by conducting tests on relevant UAS power/propulsion system components to evaluate the system effectiveness. Use modern sensor and actuator technology to monitor and control energy flows and regeneration; and demonstrate management of system operations such that the system can effectively switch among individual (engine or motor) modes when applicable, etc.

PHASE III DUAL USE APPLICATIONS: Military applications include UAS platforms that employ small turbines, small internal combustion engines (ICE) and/or hybrid propulsion concept vehicles. Commercial applications would include high end UAS systems.

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2. Junghsen Lieh, Eric Spahr, Alireza Behbahani, and J. Hoying, "Design of Hybrid Propulsion Systems for Unmanned Aerial Vehicles," 47th AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit, San Diego, California, 2011.

3. "Modeling of Hybrid Electric UAV Propulsion System in Simulink" - Junghsen Lieh, Alireza Behbahani, John Hoying, 58th IIs 2012, ISA, 2012.

4. "Conceptual Design and Simulation of a Small Hybrid-Electric," University of California—Davis, Unmanned Aerial Vehicle, Frederick G. Harmon, Andrew A. Frank, and Jean-Jacques Chattot.

5. "Sensing Challenges for Controls and PHM in the Hostile Operating Conditions of Modern Turbine Engine," (Postprint), A. Behbahani and K. Semega, July 2008, (Uploaded in SITIS 6/10/11).

6. "Robust Hybrid Controller Design Based on Feedback Linearization and μ Synthesis for UAV," Liwei Qiu, Guoliang Fan, Jianqiang Yi and Wensheng Yu, "Proceedings of the 2009 Second International Conference on Intelligent Computation Technology and Automation," - Vol. 01, IEEE Computer Society Washington, DC, USA. ISBN: 978-0-7695-3804-4.

7. "Mission-level Autonomy for Unmanned Vehicle Teams," David Scheidt, The Johns Hopkins University, Applied Physics Laboratory.

KEYWORDS: hybrid, propulsion, controls, remotely piloted aircraft (RPA), unmanned air vehicle, UAV, controllers, propulsion systems, electric power, hybrid systems, velocity, computer programs, optimization, intelligence, disasters, monitoring, networks, unmanned, electricity, lithium batteries, surveillance, reconnaissance, aspect ratio, electric motors, internal combustion engines

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AF141-070 TITLE: Lithium-Ion (Li-ion) Battery Electrolytes using Nonflammable, Room-Temperature Ionic Liquids

KEY TECHNOLOGY AREA(S): Air Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: The purpose of this effort is to develop an ionic liquid based electrolyte for lithium-ion batteries that is nonflammable, has a high ionic conductivity over a wide temperature range, and is electrochemically stable to ensure long battery lifetimes.

DESCRIPTION: Rechargeable Li-ion batteries can fail violently when subjected to an internal electrical short, are overheated, crushed, or when then are overcharged/overdischarged. Recent events such as the grounding of a commercial aircraft due to Li-ion battery fires demonstrate that the safety of Li-ion batteries is of major concern. Of particular interest are improvements in safety for Li-ion batteries with the use of electrolytes based on nonflammable, room temperature ionic liquids. These new batteries will demonstrate improved safety under various abuse/extreme conditions while also increasing the battery performance at military relevant operating temperatures (-40 to +75 degrees C), storage temperatures (-55 to +85 degrees C), and at high charge/discharge rates (capable of charging/discharging at greater than a 20C rate). These innovative solutions should also place an emphasis on reducing the acquisition costs of these alternative batteries to levels that will make them cost competitive with existing Li-ion, lead-acid, and nickel-cadmium military batteries in terms of acquisition and life cycle.

During Phase II, the offeror will produce a prototype battery for a chosen Air Force (AF) application that involves aircraft emergency and pulse power using the advanced electrolytes. The offeror will also compare the performance to the baseline battery system. The Phase II prototype should be delivered to the AF for additional testing and evaluation. At the end of the contract, the offeror should also demonstrate the prototype at Wright-Patterson AFB to outbrief technology advancements.

PHASE I: Propose an innovative nonflammable electrolyte based on room temperature ionic liquids for rechargeable Li-ion batteries. Li-ion batteries will have equivalent or better energy and power density capability in relation to current high-rate Li-ion technology. Present experimental and other data to demonstrate feasibility of innovative solution. Prepare initial transition plan.

PHASE II: Produce an alternative safer Li-ion battery using the developed nonflammable electrolytes for use in an Air Force aircraft emergency and pulse power application (TBD during Phase I). The prototype battery or module size will also be determined during Phase I. Provide cost projection data to substantiate the design, performance, operational range, acquisition, and life cycle costs. Refine transition plan and business case analysis.

PHASE III DUAL USE APPLICATIONS: The military applications include aircraft emergency and pulse power, electric tracked vehicles, unmanned systems, hybrid military vehicles, and unmanned underwater vehicles (UUVs). Commercial applications include hybrid and electric vehicles, portable electric drills, etc.

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KEYWORDS: lithium-ion, batteries, non-flammable, ionic liquid, electrolyte, safety

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AF141-071 TITLE: Safe, Large-Format Lithium-Ion (Li-ion) Batteries for Aircraft

KEY TECHNOLOGY AREA(S): Air Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: The purpose of this effort is to develop safe, large-format aircraft Li-ion batteries where propagation of a cell failure is minimized.

DESCRIPTION: Rechargeable Li-ion batteries can fail violently when subjected to an internal electrical short, are overheated, crushed, or when then are overcharged/overdischarged. Recent events such as the grounding of a commercial aircraft due to Li-ion battery fires demonstrate that the safety of Li-ion batteries is of major concern. Of particular interest are improvements in safety for large-format aircraft Li-ion batteries by eliminating cell-to-cell thermal transport and cell failure propagation. These new batteries will demonstrate improved safety under various abuse/extreme conditions while also increasing the battery performance at military relevant operating temperatures (-40 to +75 degrees C), storage temperatures (-55 to +85 degrees C), and at high charge/discharge rates (capable of charging/discharging at greater than 20C rate). These innovative solutions should also place an emphasis on reducing the acquisition costs of these alternative batteries to levels that will make them cost competitive with existing Li-ion, lead-acid, and nickel-cadmium military batteries in terms of acquisition and life cycle.

During Phase II, the offeror will produce a prototype battery for a chosen Air Force (AF) application that involves aircraft emergency and pulse power using the advanced configuration. The offeror will also compare the performance to the baseline battery system. The Phase II prototype should be delivered to the AF for additional testing and evaluation. At the end of the contract, the offeror should also demonstrate the prototype at Wright-Patterson AFB to outbrief technology advancements.

PHASE I: Develop an innovative, safe, large-format rechargeable aircraft Li-ion battery that does not have cell-to-cell propagation of a cell failure. Li-ion batteries will have equivalent/better energy/power density capability relative to current high rate Li-ion technology. Present experimental and other data to demonstrate feasibility of proposed solution. Develop initial transition plan.

PHASE II: Produce alternative, safer Li-ion battery using the developed configuration for AF aircraft emergency/pulse power application (TBD during Phase I). The prototype battery/module size will be determined during Phase I. Provide cost projection data substantiating the design, performance, operational range, acquisition, and life cycle cost. Refine transition plan and business case analysis.

PHASE III DUAL USE APPLICATIONS: The military applications include aircraft emergency and pulse power, electric tracked vehicles, unmanned systems, hybrid military vehicles, and unmanned underwater vehicles (UUVs). Commercial applications include hybrid and electric vehicles.

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KEYWORDS: lithium-ion, batteries, safety, rechargeable, thermal, failure, propagation

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AF141-072 TITLE: Fiber-Optic-Distributed Temperature Sensing System

KEY TECHNOLOGY AREA(S): Air Platforms

OBJECTIVE: Develop a fiber-optic-distributed sensor system that will sense bleed air leaks in the propulsion, environmental control, and thermal management systems (TMSs) to increase survivability throughout the operating mission of advanced tactical aircraft.

DESCRIPTION: Advanced tactical aircraft are required to provide protection to fire throughout the operating mission flight envelope. The aircraft structure is vulnerable to excessive temperatures over long periods of time when exposed to hot gas leaks from the propulsion, environmental control systems, and TMSs on the aircraft. The distributed temperature sensing technology would increase the survivability of fighter aircraft against bleed air leaks. The purpose of this technology would be to allow the fighter aircraft to extend the amount of time that it could engage in conducting its mission without restricting the overall flight time before a bleed air leak condition is detected. This technology allows greater accuracy in detection of bleed air leak by reducing the amount of nuisance trip indications by providing greater resolution into the high end of the trip-detection band. When a bleed air leak detect condition is reported, then this technology will decrease the maintenance support time by providing maintenance personnel with the information needed to exactly pinpoint where the root cause is located in the equipment bay or duct, improving the aircraft readiness rate. The purpose of this program is to develop a distributed temperature sensing system to provide more robust and accurate fire-protection, leak-detection alarm capabilities and improved fault diagnostic capabilities.

The existing fire-protection bleed air leak detect system technology alarm trip conditions are highly dependent on multiple conditions. The individual alarm trip points can vary over very large tolerances and are dependent on mission flight profile, ambient temperature, air speed before and during the bleed air leak detect alarm condition, engine conditions, air flow through equipment bay, and temperature over the sensor. Future aircraft are continuing to look at enhanced mission operating characteristics that demand longer flight times at low and fast airspeeds in hot ambient environments. The current methods used for detecting bleed air leaks in fighter aircraft equipment bays will continue to push the limits of the conventional technology alarm trip points and diagnosing and isolating the exact fault location along the temperature sensors will become increasingly difficult on future aircraft. The new fiber-optic technology offers the ability to accurately sense the temperature of the air temperature in the surrounding area adjacent to the sensors with the ability to provide enhanced fault diagnostics for future fighter aircraft. Innovation is required to reduce the size and weight of the optical time domain reflector meter instrumentation and routing of the fiber optics inside a small fighter aircraft equipment bay. The fiber-optic-distributed temperature sensing electronic system must be able to sense up to 565 degrees for alarm temperatures in a hot air equipment bay environment up to 15 m in length in eight channels. The spatial resolution must be 0.127 m at an acquisition rate of 0.5 Hz. The maximum power consumption should be 33 W at 28 VDC. The aircraft interface shall be IEEE 1394b “Firewire”

SAE AS5643 compliant to industry standards. The operating temperature ranges from -60 to 160 degrees F and pressures ranging from atmospheric pressure down to 50,000 feet in altitude. In addition, the sensor probe must be compatible with fuel and fuel vapors. The sensor system must be intrinsically safe and survive under shock and vibration loading during takeoff, landing, and mission profiles. Prime contractor collaboration is highly encouraged.

PHASE I: Design and demonstrate feasibility of a fiber-optic-distributed temperature sensing used for detecting bleed air leaks in fighter aircraft. Control and operation of a feasible fiber-optic sensor system can be shown by laboratory investigations. Develop a transition plan and business case analysis.

PHASE II: Full development of a production representative fiber-optic-distributed temperature sensor system and demonstrate in a simulated relevant fighter aircraft bay thermal environment. Abbreviated developmental survey testing of the system under MIL-STD. A full-scale, simple-to-operate working prototype system is desired for presentation and demonstration at WPAFB, and delivery to the Government at the completion of program for additional evaluation. Refine transition plan and business case analysis.

PHASE III DUAL USE APPLICATIONS: The technology has applications both for military and commercial aircraft. This type of distributed temperature sensing has other potential applications in leak/fault detection in industrial cooling applications and power plants.

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2. Graham Warwick, "Sense of Shape: NASA takes step toward active wing-shape control with flights of new fiber-optic sensor," *Aviation Week & Space Technology*, pp. 63-64, July 28, 2008.

KEYWORDS: bleed air leak detection, fire protection system, fiber optic sensing, optical time domain reflectometer, fiber Bragg grating, optical backscatter reflectometer, instrumentation

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AF141-073 TITLE: Single-port Fiber-optic Probe for Imaging and Spectroscopy in Practical Combustion Systems

KEY TECHNOLOGY AREA(S): Air Platforms

OBJECTIVE: Develop and demonstrate a compact, fiber-optic-based probe enabling multidimensional imaging and line-of-sight absorption spectroscopy for local measurements of gas properties (e.g.,temperature and combustion species) in practical combustion systems.

DESCRIPTION: Specifically desired is a multi-purpose probe enabling a number of key measurements in practical devices that include, but are not limited to, gas turbine engine main combustors and augmentors, pulse detonation and rotary detonation engines, scramjets, rockets engines, and internal combustion engines.

A successful probe will be designed to be inserted through a single port in any such aeropropulsion device for optical access to the flow path of interest. Engine ports are typically be <50 mm in diameter. A probe with a smaller diameter (down to as small as 3 mm) is preferred to facilitate access to many engine geometries. A clear pathway to the port from outside the engine is generally not available; therefore, the envisioned instrumentation must provide connectivity to the probe by way of a flexible umbilical or similar arrangement. The probe will likely be exposed to high temperatures (potentially up to 1100 degrees C); therefore, successful probe instrumentation must be constructed of high-temperature materials, or actively cooled as necessary. The probe should be configurable to allow for multiple measurement types. At a minimum these must include fiber-optic-coupled multidimensional (2D and/or 3D) imaging of combustion spectral emission from chemiluminescent species (e.g., CH*, OH*, C2*, etc.), polyaromatic hydrocarbons (PAHs), and other naturally occurring spectral emitters generated during fuel combustion. Ideally such emission should be measured across the ultraviolet/visible spectral range to include 200 to 800 nm. The probe must also be configurable to allow line-of-sight-integrated absorption measurements in the near-infrared region (i.e., 1325 to 1665 nm for the purposes of this solicitation) for determining gas temperature and concentrations of key species (e.g., H2O, etc.). Access to the mid-infrared region and combustion species with strong absorptions there (e.g., CO, CO_2, NO, etc.) is also highly desired.

Although the probe must be capable of UV/visible chemiluminescence imaging and near-infrared absorption spectroscopy, expandability to accommodate other measurement configurations is highly desirable. These other configurations can include, but not be limited to: laser-induced fluorescence, laser-induced incandescence, particle-image or molecular flow-tagging velocimetry, and various nonlinear techniques such as coherent anti-Stokes Raman scattering spectroscopy.

A second penetration for light delivery or signal collection in conjunction with some of the expanded optical capabilities mentioned above could be available, but the chemiluminescence imaging and near-infrared absorption measurements must be achieved by means of a single penetration. Because the topic stipulates that only a single penetration through the engine casing is permitted, absorption-based approaches must rely on pitch-and-catch or backscatter geometries compatible with a single-ended device. All optical components associated with the imaging and spectroscopic elements of the probe must be hardened, like the probe, for high-temperature operation. Associated software should include, but not be limited to, temperature, key species concentrations, flame location, local and global fuel-to-air equivalence ratio, heat release, velocity, vorticity, soot volume fraction, etc. Some of these measurements will be achievable with the chemiluminescence imaging and near-infrared absorption spectroscopy that are the principal subjects of this topic; others will require some or all of the enhanced measurement capabilities (fluorescence, incandescence, velocimetry, CARS, etc.) indicated above and need not be accomplished under Phase I and Phase II programs awarded through this topic solicitation. Furthermore, the associated post-processing software for interfacing with these high-bandwidth data must be capable of various linear and nonlinear spatial and temporal analyses.

PHASE I: Design a probe, with alpha-version software and demonstrate the feasibility of meeting target performance metrics through simulation of device operation and experimental investigation with a breadboard or brassboard device. Demonstration must address optical configurations for imaging of spectral emission and near-infrared absorption; thermal management; and high-bandwidth operation.

PHASE II: Deliver a thoroughly ruggedized version of the probe and associated data-processing software that address all of the hardware and software performance metrics defined in the topic solicitation and refined during the Phase I effort. Demonstrate the probe and its software in a practical test environment associated with an Air Force aeropropulsion application to be defined in conjunction with Air Force personnel during the Phase II effort.

PHASE III DUAL USE APPLICATIONS: Phase III applications are improved measurement and diagnostic tools for sensor access in practical combustion hardware, to enhance sustainability of current and legacy aeropropulsion systems including gas turbine, detonation powered, scramjet, rocket, and internal combustion engines.

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KEYWORDS: high temperature, sensors, nonintrusive, ultraviolet, infrared, chemiluminescence, software, imaging

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AF141-074 TITLE: Developing Failure Stability in High-Reliability Sensor Design and Applications

KEY TECHNOLOGY AREA(S): Air Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop an innovative engine sensor system for harsh environmental conditions that is more reliable and affordable than existing passive control and monitoring sensors for legacy and future turbine engine platforms.

DESCRIPTION: A significant challenge in developing aerospace engine and vehicle sensor systems is reliability. The issues involve multiple considerations, including the use environment, materials, architecture, redundancy, and communication. Sensor systems are also susceptible to noise and other sources of error that make understanding and effectively solving reliability problems difficult. On new platforms, the number of sensors, their performance requirements, and the environmental constraints are increasing due to control system designs that provide increased performance and efficiency. However, the fielded reliability of state-of-the-art (SOA) sensor technology, including active and passive sensors, has not correspondingly kept pace with new engine designs. SOA engine position and feedback sensors operate over temperatures of 200 degrees C. They typically are designed for a mean time between failure (MTBF) reliability over 100,000 flight hours. However, fielded application data show that mean time between maintenance actions (MTBM) and MTBF reliability can be an order of magnitude (10x) or lower, compared with predicted capability. SOA temperature, pressure, and diagnostic (vibration) sensors operate at gas temperatures between -55 degrees C to over 650 degrees C and are also top maintenance drivers due to lower reliability values achieved compared with SOA design and test experience. Reliability performance in harsh fielded conditions is therefore a limiting factor in achieving high reliability and low maintainability in control systems for new platforms. Current employment of physical redundancy, sensor fusion, instrumentation, and software health management techniques are used to facilitate system reliability and meet design goals, but system cost and reliability for advanced systems are issues that remain to be addressed. Recent developments in materials science, micro-electromechanical (MEMS) systems, and communications approaches are smart sensing techniques that will enable new approaches to improve the reliability of sensing and control systems employed in aerospace systems. It is desirable to improve advanced sensor system reliability by design and evaluation of new approaches that accommodate existing hardware and software architectures to the maximum extent practical. Sensors for critical engine measurements include temperature, pressure, speed, and position. Investigation of passive and active redundancy approaches in smart sensor design, enhanced environmental capability, mechanical design, and MEMS component reliability are appropriate. Passive redundancy is a way to ensure against failure by providing alternate (unpowered) pathways for operation of mechanical or electrical loads when one path fails. Enhanced environmental tolerance using new material and design systems allow operation with higher thermal and vibrational loads while reducing wear and damage. Smart sensing concepts can employ numerous methods to increase reliability including measuring electrical signals directly in mitigating and flagging environmental effects such as corrosion and wear and increasing reliability. In Phase II, a new sensor architecture will be developed at an appropriate partitioning and integration level that employs advanced analytical, electrical, or mechanical hardware techniques that improves reliability compared with current SOA passive or active sensors. Measurement systems for pressure, temperature, and acceleration are suitable candidates for improvement. Demonstration of sensor system reliability improvement using modeling, accelerated life testing or other appropriate stress testing methodologies is required. Delivery of prototype hardware, software, and algorithms to the Air Force is required to facilitate further testing after Phase II. Working with an engine original equipment manufacturer (OEM) or control system vendor is recommended to enhance the relevance and transition ability of the final research product.

PHASE I: Demonstrate the feasibility of applying high reliability and failure stability design techniques to an advanced smart sensor, temperature, pressure, or position sensing system for a turbine engine. Evaluate improvements over current SOA engine controls. Develop preliminary transition plan and business case analysis.

PHASE II: Develop and refine the Phase I concepts by fabricating prototype hardware and software. Demonstrate the high reliability sensor concept on a realistic turbine engine control system. Test the hardware and software in a realistic engine environment. Develop preliminary transition plan and business case analysis.

PHASE III DUAL USE APPLICATIONS: This technology is applicable to Air Force, Navy and Army gas turbines, as well as commercial aircraft engines. Sensor architectures that improve reliability also apply to process control and unmanned air vehicles (UAVs), including aircraft data integrity applications.

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KEYWORDS: high reliability, sensors, fault tolerance, failure stability, smart sensors

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AF141-075 TITLE: Improved Design Package for Fracture Mechanics Analysis

KEY TECHNOLOGY AREA(S): Air Platforms

OBJECTIVE: Develop an improved software design package that better accounts for short crack effects in crack growth.

DESCRIPTION: Linear elastic fracture mechanics (LEFM) methods are used extensively in aerospace to perform crack growth life predictions. These methods are sometimes erroneously applied in cases where the initial defect size assumptions are outside the range of strict LEFM applicability. Typically this occurs when starting flaw size assumptions are on the same order as the length scale of the microstructure. One relevant example would be titanium alloys optimized for slow fatigue crack growth.

This technical deficiency leads to significant errors or uncertainty in the life predictions that can result in unreliable designs or excessive conservatism. In order to facilitate the design of more reliable & efficient aerospace structures, methods are needed to establish when conventional LEFM methods may be applied with confidence and new methods are required for microstructurally short cracks, where LEFM is not applicable.

Methods are desired that accurately determine where conventional LEFM approaches can be applied based on flaw size, orientation, material, and applied loading. Methods for accurate damage propagation prediction outside of the traditional LEFM regime (small crack growth) are also desirable. A physically accurate treatment of the problem is favored over empirical approaches. Extensions of previously existing packages are favored to enhance opportunities for commercialization.

PHASE I: Develop a method for damage tolerant design with flaw sizes below the range of LEFM applicability (short crack regime). The method should include the ability to account for material, crack size, shape, and applied loading. The method should be validated using coupon tests. A development plan to mature the method as a viable design tool must be developed.

PHASE II: The Phase II effort will implement the developed method(s) in a validated design package. The design package should be effective in both the short crack and long crack regimes. Prototype software versions are desired for government evaluation. Small evaluation efforts with aerospace original equipment manufacturers (OEMs) are encouraged to enhance opportunities for commercialization.

PHASE III DUAL USE APPLICATIONS: Fracture mechanics software applications are used extensively throughout the commercial aerospace, marine, civil, and automotive engineering communities.

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KEYWORDS: crack growth, damage tolerance, fatigue, fracture mechanics, short crack growth

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AF141-076 TITLE: Modular Flexible Weapons Integration

KEY TECHNOLOGY AREA(S): Air Platforms

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OBJECTIVE: Develop store carriage technology for advanced aircraft that will increase weapons load out, reduce drag, extend range, and not compromise survivability over current carriage techniques.

DESCRIPTION: The mission of tactical, strike, and attack aircraft, manned or unmanned, is to deliver an effective load of weapons to the designated target with minimal collateral damage. In order to accomplish this mission, both external and internal store (bombs, missiles, fuel tanks, electronics pods, etc.) carriage methodologies have been used in the past with success. Innovative external carriage and release concepts are required to meet the need to carry larger weapons payloads with minimal impact to range and survivability of the current and future aircraft.

The existing F-15, F-16, and F-18 fleet carry external weapons, as will all three variants of the F-35 aircraft. The variety of stores carried externally is challenging to all aspects of weapons integration, from simply fitting the stores onto the airframe, to aircraft handling and control. Separation is especially difficult as additional stores are added; the aerodynamic interactions become more interdependent. A good example is the F-18E/F where significant effort was required to counter the adverse fuel tank aerodynamics in order to allow store separation (see reference 2, 14-1 to 14-12). In that particular case, all pylons on the aircraft were toed 4 degrees nose outboard and additional structural issues had to be addressed. Modifications of this type can be effective but lack the elegance desired for effective integration of externally carried weapons.

Many studies have been performed looking at methods for reduced drag, improved separation and even reduced impact on aircraft signature for external store carriage. In the early 1970s, conformal carriage studies were conducted for the F-4 Phantom to reduce drag. Additional studies have addressed conformal carriage, semisubmerged carriage, and light weight structures (shrouds, etc.) mounted to the external store for improved carriage performance.

External carriage and radar cross section seem to be at odds; however, innovative methods for shape modification, appropriately designed external pods, and specialized materials need to be explored to improve weapons load out while maintaining acceptable signature levels.

One of the largest volume stores carried on most aircraft is the external fuel tank. These all have a similar look to maximize the volume of fuel that can be carried. Conformal fuel tanks and collapsible concepts have been put forth as reduced drag alternatives with varying degrees of acceptance. One recent study has shown that aerodynamic shaping can be used to reduce drag and improve store separation characteristics near these large external stores (see reference 5). This area has a large potential for improved range/energy efficiency.

With this background, the Air Force is interested in technologies that can improve delivery of weapons to the target. The scale of the platform to be considered is representative of the F-35 both in size and flight regime of interest. The goal is to have multiple innovative external carriage concepts produced with computational, as well as experimental, evidence that the concepts will perform with better characteristics than traditional external carriage. Considerations of impact on aircraft range, weapons separation, performance and handling, as well as survivability, should be considered.

PHASE I: Multiple unique external carriage concepts will be developed. An engineering/preliminary design review (form, fit, function, weights and balances) will be conducted to evaluate the potential of candidate concepts to yield achievable performance gains. Limited computational/experimental data will be required to evaluate concepts. Plan testing and refinement of the most successful concepts in Phase II.

PHASE II: During this phase, evaluation and refinement of concepts will be achieved. Both computational and experimental testing and validation of concepts will be accomplished. The analysis should include computational and/or experimental assessment of drag, separation, and signature. Possible preparation for flight test may be required depending on the concepts explored and funding level.

PHASE III DUAL USE APPLICATIONS: Weapons carriage technologies developed could be applied to legacy military aircraft for improved performance, increased weapons load out, etc. Commercially, extended range fuel tanks and drag reduction technologies may be applied.

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KEYWORDS: internal carriage, external carriage, store carriage, conformal carriage, semisubmerged carriage, tandem carriage, radar cross section, store separation

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AF141-080 TITLE: Air Cycle Toolsets for Aircraft Thermal Management System (TMS) Optimization

KEY TECHNOLOGY AREA(S): Air Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual

use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Development of complementary hardware and software toolsets which allow assessment and characterization of different military aircraft air cycle or hybrid-cycle thermal management system architectures.

DESCRIPTION: Current tactical aircraft face enormous challenges associated with increasing operational envelope while reducing fuel burn. To that aim, there is a growing desire within the power and thermal systems community to explore the hybridization of complementary thermal cycles as a means for improving tactical aircraft thermal management system (TMS) energy efficiency and dynamic responsiveness. To accomplish this, a flexible set of air cycle hardware components coupled with validated computational models are required for hardware-in-the-loop system development and performance assessment activities. It is envisioned that these toolsets could be used to explore impacts of different potential air cycle system (ACS) configurations on overall vehicle TMS performance in both steady state and dynamic operation. The data obtained from these studies could then be used for assessment and optimization of vehicle TMS against developer-defined mission parameters including vehicle speed, altitude, and accessory power and thermal needs.

To realize this vision, several significant technical challenges must be addressed. Specifically, co-development of rugged ACS wheel sets (compressors and turbines) which incorporate interchangeable, reusable, and reliable pneumatic and rotational interconnects with complementary computational models which facilitate selection of appropriate wheel-pairs is necessary. It is anticipated that this activity will result in the demonstration of a series of radial or axial air cycle compressors and turbine wheels that can be mounted (onto a drive stand or high-speed rotational drive) into three or more different configurations in order to explore potential tactical aircraft mission scenarios. Further, these components would permit operation in conjunction with other TMS subsystems (cooled air to vapor compression systems) to explore promising vehicle-level TMS architectures. A set of complementary computational models is also required to analytically predict thermodynamic performance, aerodynamic performance, and consider mechanical safety of the high speed rotational machinery tools.

For the purposes of this tool demonstration, all componentry should be designed to be operated onto a typical high speed (60 krpm, 10 to 100 kWth, 300 kWrot) drive stand (dynamometer) or similar high-speed motor with minimal rebalancing of each of the ACS wheels between tests. Further, the offeror must demonstrate that an appropriate number of wheel pairs could be independently configured such that the final toolset is flexible and not an ACS point design. Phase II deliverables should include two to three compressor wheel sets, one to two turbine wheel sets, reconfigurable ducting for pneumatic connectivity, and complementary Matlab (or similar environment) open-source codes.

A particular design point of interest includes delivery of 1 pps (lb/s) of air at 40 to 70°F at a delivery pressure of no less than 100 psi from ambient air (~90°F, 14.7 psi). A secondary design point would include delivery of 1 pps of air at 40°F from precompressed 300 psi, 100°F supply air. Power generation is of secondary importance.

PHASE I: In context of modern high performance aircraft TMS specifications, demonstrate feasibility of developing a set of ACS hardware toolsets which meet the topic objectives. Develop and demonstrate a set of computational toolsets to facilitate appropriate and safe pairing of compressor and turbine wheel sets.

PHASE II: Develop and demonstrate a prototype version of the ACS wheel sets designed under the Phase I activity. Demonstrate that these tools can be used to simulate two or more vehicle ACS configurations in terms of power, pressure ratio, or discharge temperatures based upon the notional vehicle’s performance desirements developed during the Phase I. Identify necessary facility or testing requirements necessary to operate the tools over USAF relevant operational tactical fighter mission scenarios.

PHASE III DUAL USE APPLICATIONS: Commercial applications include development of air cycle units for commercial aircraft APUs, ground carts, and pressurization units.

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1. T.R. Ensign and J.W. Gallman, "Energy Optimized Equipment System for General Aviation Jets," Proceedings of the 44th AIAA Aerospace Sciences Meeting and Exhibit, January, 2006 (228).

2. R. Slingerland and S. Zandstra, "Bleed Air Versus Electric Power Off-takes from a Turbofan Gas Turbine over the Flight Cycle," Proceedings of the 7th AIAA Aviation Technology, Integration and Operations Conference, September 2007 (7848).

3. E.A. Walters and S. Iden, "Invent Modeling, Simulation, Analysis and Optimization," Proceedings of the 48th AIAA Aerospaces Sciences Meeting, January 2010 (287).

KEYWORDS: aircraft thermal management, air cycle systems, air cycle systems, ACS, environmental control systems, ECS, aircraft power and thermal subsystems

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AF141-081 TITLE: Launch Vehicle Systems Intended to Execute Suppressed Trajectories for Hypersonic Testing

KEY TECHNOLOGY AREA(S): Air Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop an innovative approach(es) for new and/or existing launch systems to execute suppressed trajectories for hypersonic flight testing. Perform analysis and testing to mature technology, validate models, reduce risk, and demonstrate capability.

DESCRIPTION: The Air Force is working on next-generation hypersonic systems for various missions, including high-speed strike, space access, and penetrating intelligence, surveillance, and reconnaissance (IS&R). Conducting affordable flight testing is necessary to understanding physical phenomena, validating models, and building stakeholder support. In hypersonic testing, getting the test article into the necessary test window with the required flight environment can be challenging, given existing booster systems. Getting into relevant test windows for extended test times usually requires challenging suppressed trajectories that state-of-the-art booster systems have difficulty achieving. A trajectory can be considered suppressed if it does not utilize exoatmospheric flight prior to entering hypersonic flight environments.

As an example, the HIFiRE-2 Program required a suppressed trajectory for propulsion testing. The flight vehicle used three solid boosters, coasting gravity turns, and risky timing techniques to ignite upper stages. This suppressed trajectory included multiple unpowered passes through transonic flight, creating high uncertainty.

Capabilities of systems to be developed under this effort include one or more of the following: reduction of software verification and validation, simplification in meeting test range safety requirements, simplification in test range integration, reduction of uncertain flight environments (e.g., transonic), reduction in stages, reduction in additional hardware, reduction of undesirable loads on the payload (e.g., acoustic, vibration, heating), maximization of test time, reduction of ground infrastructure and personnel, reduction in aerodynamic loads, and allowing for a more vertical launch direction from the ground (not applicable to air-launched systems). For the purposes of this SBIR solicitation, these desired capabilities are considered of roughly equal importance.

The approaches developed under this effort will need to be demonstrated as enabling at least one government-supplied test window. It is anticipated that test windows defined by parameters such as dynamic pressure, Mach number, angle of attack, and flight path angle will be provided. A sample test window includes Mach 4 to 8 and dynamic pressures from 1,000 psf to 3,000 psf. The offeror's proposed approach should maximize coverage of the government-supplied test windows. These test windows are subject to modifications during Phase I.

Candidate technology approaches could include new booster systems, fin set upgrades for existing systems, new control algorithms and effectors, trajectory shaping, and/or rocket motor throttling/gimbaling. A proposed solution could include a single or combination of methods.

Both Phase I and Phase II will consist of an appropriate level of design and systems engineering efforts to understand what it will take to make the proposed solution(s) operational. These efforts should address all lifecycle issues but focus in on the demonstrations that will be conducted in Phase II.

For the purpose of Phase I proposals, the payload can be assumed to have the following characteristics: 300-lbm gross weight, 2-ft length, 6-inch diameter, 30-percent front is a blunted ogive with the rest being a cylinder, and 20-percent increase in drag on the stage attached to the payload (to account for inlets, exhaust ports, and/or surface irregularities). It is desirable for technology approach(es) to be scalable to systems supporting larger payloads and/or more energetic trajectories.

Computational resources from the DoD Supercomputing Resource Center (DSRC) will be provided at no additional cost for use on this effort to appropriately cleared contractor personnel.

PHASE I: Investigate innovative approaches to achieve the test windows. Define the system requirements for the solution(s). Define trajectories for the test windows. Early verification and validation by analysis of the solution(s) to achieve reference trajectories, meet requirements and meet testing needs. Develop integration, verification and validation plans for the entire system and tests for Phase II.

PHASE II: Further refine and develop a detailed-level design of proposed solution(s). Update as needed the integration, verification, and validation plans focusing on the Phase II efforts. Fabricate, assemble, and integrate the items for testing. Conduct testing to mature the technology solutions. Tests will provide insight into how the solution(s) support suppressed trajectories. At the end of Phase II, viability is shown with testing, design analysis, and future development planning.

PHASE III DUAL USE APPLICATIONS: Potential commercial applications include providing launch services and/or launch hardware to support development of hypersonic technology and systems such as a hypersonic IS&R aircraft, an upper stage for a space-access vehicle, or a tactical hypersonic missile.

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2. Jackson, K., Gruber, M., and Bucceellato, S., "HIFiRE Flight 2 Project Overview and Status Update 2011," 17th AIAA International Space Planes and Hypersonic Systems and Technologies Conference, AIAA-2011-2202, San Francisco, CA, April 11-14, 2011.

3. Bolender, M., Dolvin, D., and Staines, J., "HIFiRE 6: An Adaptive Flight Control Experiment," 50th AIAA Aerospace Sciences Meeting including the New Horizons Forum and Aerospace Exposition, AIAA-2012-0252, Nashville, TN, January 9-12, 2012.

4. Walker, S., et al., "The DARPA/AF Falcon Program: The Hypersonic Technology Vehicle #2 (HTV-2) Flight Demonstration Phase," 15th AIAA International Space Planes and Hypersonic Systems and Technologies Conference, AIAA-2008-2539, Dayton, OH, April 28 - May 1, 2008.

5. Hellman, B., et al., "Critical Flight Conditions of Operation Rocketback Trajectories," AIAA Space 2012 Conference & Exposition, AIAA-2012-5208, Pasadena, CA, September 11-13, 2012.

KEYWORDS: hypersonic, trajectory, suppressed trajectory, flight testing, launch vehicle, booster, rocket, high speed

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AF141-082 TITLE: Development of Approaches to Minimize Icing in Aircraft Heat Exchanger/Condenser Applications

KEY TECHNOLOGY AREA(S): Air Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop and evaluate innovative concepts to minimize icing in heat exchanger/condenser applications associated with an air cycle machine for aircraft cooling requirements.

DESCRIPTION: The demand for thermally unconstrained operations for aircraft has been driving the research of integrated thermal management designs for several years. Recent turbine engine efforts have focused on increasing the available air heat sink to help meet thermal requirements affected by the steady growth of avionics heat loads. Use of these cooler air heat sinks to dump aircraft heat loads can be improved through additional analysis/research of methods to reduce the impact of icing that may occur in heat exchanger/condenser components associated with aircraft thermal management. Approaches might include the development of ice resistant (ice phobic) coatings and/or the design of condenser equipment that partitions passageways or redirects available airflows to minimize icing conditions.

Condenser icing is a concern for aircraft air conditioning systems using a high-pressure water separator to remove moisture from cooling air supplied to equipment and the cockpit. A high-pressure water separator includes an air-to-air condenser heat exchanger. The condenser causes water droplets to form on the hot side fin surfaces by transferring heat from a cold side air stream. The condensed water droplets are then removed by a centrifugal device, and cool, relatively dry air is supplied to the equipment and the cockpit. In general, a cross-flow designed condenser may operate in a moist environment, with warm air entering at station 1 and exiting at station 3 after being cooled by cross-flow air generated by a cooling turbine at station 2. Both the hot and cold sides of the condenser contain moisture and have the potential to form ice. Table 1 provides typical operating conditions for this type design. Note that at station 3, the temperature is only 3°F above freezing. Current state-of-the-art condensers operate ~ 8 to 12°F above freezing to minimize ice build-up on the condenser heat transfer surfaces. A lower allowable temperature at station 3 would reduce the amount of air required to cool equipment and condition the cockpit. This lower air flow would reduce the amount of energy extracted from the propulsion system, resulting in lower fuel consumption for the same mission.

Table 1. Condenser Operating Conditions for Typical High Pressure Water Separator Configuration

Station (ppm)	Flow (psia)	Pressure	Temp (F)	Humidity (grains/lbm dry air)
1	62.2	90.8	93	175
2	236.4	44.4	-16.4	14
3	62.2	87.3	35	175

A condenser heat exchanger designed to the performance requirements described in Table 1 is provided for reference. For the cross-flow design, the hot side inlet may have 90 to 95 percent as the main core with 5 to 10 percent reserved for anti-ice flow passages. The aluminum heat exchanger configuration would include a hot side flow length of 16.5 inches, a cold side flow length of 2.15 inches, and a no flow length of 6 inches. The selected fins have a height of 0.25 inch and the fin pitch is 15.6 fins per inch.

Collaboration and/or partnership with an Original Engine Manufacturer (OEM) and/or a Weapon Systems Company (WSC) to gain additional insight of operational requirements (such as heat transfer medium(s), flow rates, temperatures, pressures, heat transfer, life, reliability, structural requirements, etc.) and constraints (size, weight, potential installation locations, attachment methods, material compatibility, etc.) is highly encouraged for this effort. A final presentation at WPAFB will be conducted at the end of the Phase II effort.

PHASE I: Demonstrate the feasibility of proposed innovative concepts to minimize icing in heat exchanger/condenser components that are part of an aircraft turbine engine thermal management system. Identify the anticipated merits of the preferred solution related to thermal performance, manufacturing, installation, durability, and cost.

PHASE II: Fully develop and analyze the selected Phase I solution for a range of heat load/heat sink flow conditions. Develop subscale and/or full-scale hardware to demonstrate the selected approach and establish technology and manufacturing readiness level.

PHASE III DUAL USE APPLICATIONS: The improved heat exchanger concept will have primary applications in advanced military fighter aircraft and possibly future commercial applications.

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1. Alizadeh et al., "Dynamics of Ice Nucleation on Water Repellent Surfaces," American Chemical Society, Langmuir 2012, Vol. 28, pp. 3180-3186.

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KEYWORDS: thermal management, air cycle system, heat exchanger, condenser, ice phobic

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AF141-083 TITLE: Smart Aircraft Conceptual Design in Multidisplinary Design Optimization

KEY TECHNOLOGY AREA(S): Air Platforms

OBJECTIVE: Develop and demonstrate a smart conceptual design tool to enable improved estimates of performance, including weight and balance associated with early definition of subsystems layout and integration.

DESCRIPTION: A conceptual design is characterized as authentic (a closed design) when it includes an authentic development process to define primary parameters that predict the aircraft's major components and attributes: airframe (could be manufactured), it's aerodynamic shape (promises flight worthiness), and its propulsion (performance could be achieved). In such a development process, basic engineering and technology assumptions are made. These must be evaluated by further rigorous analysis and/or limited experiments (such as wind tunnel test). This work either verifies the goodness of the design or directs the need for change; specialists are part of the team. When design satisfaction is achieved (low technical risk), a much larger design-manufacturing-administrative team, may then be assigned-and their associated large support funding. This smart conceptual design approach shall differ from the major aircraft industry; it will not likely be able to afford major technical computational and 3-D graphics tools (CATIA, Unigraphics, etc.) and the dedicated individuals who must retain full proficiency in their use. It also differs in that the small team designer(s) must have broader expertise in aeronautical science than one who is tasked only with complex graphical configuration development. The usual fallback from these advanced tools, for the limited aircraft industry, is the drafting board. It provides integration; the external aircraft shape (a three-view drawing) with the internal subsystems (an inboard profile) in one area-on the board. However, this 2-D approach is one to be superseded with a smart semi-automation tool, possibly based on a generic algorithm to cut through the ambiguity of tentative requirements, and to produce a prioritized range of candidate concepts. This part of the tool set is to allow quick development of multiple design choices by a small team or single designer. The primary conceptual design parameters for either the major or limited companies are: the external aerodynamic shape/volume, the speed-altitude region of operation and the associated internal and structural architecture. The architecture of the subsystems is defined by their weight/shape/function/location/servicing and their impact on the flight balance/inertia of the overall design. The minimum, in weight definition terms, are: the structural group, the propulsion group, and the equipment group. These then sum to be the empty weight of the vehicle. The payload, fuel, and crew (if any) are added to this empty weight to define the final Normal Takeoff Gross Weight (NTOGW). The definition (the design) of the internal airframe subsystems includes: installation, strength, thermal environment, power and other special considerations. The engine installation, landing gear arrangement, and external packages also require attention. The weight of the smaller child-components of the subsystems (the sub-subsystems) shall be included in their parent subsystem weight, and their volume allowance must be included in the outer aerodynamic shape's volume. All of this defining design data will be described in lists, diagrams, tables, and with a 3-D configuration graphic(s). The latter shall show a colored rendering and also translucent views showing the major subsystems. The design is checked for stability, control, and aero-elasticity integrity. It may also be exposed to technology trades, requirement trades, configuration trades, concept comparisons, operational simulations or cost estimation. The conceptual design tool-set must be flexible (probably modular) to handle different classes of aircraft, and nonconventional arrangements. When a final design is obtained (fixed), a larger group of tech specialists takes over for the detail design and manufacturing effort.

PHASE I: Demonstrate the feasibility of an overall fixed wing smart conceptual design tool; it may contain new or modified sub-tools. It shall avoid high maintenance (dedicated human proficiency) needs, and its 3-D parametric graphics integration task must bypass the simple 2-D drafting board approach. The development of an intuitive graphics approach is a critical goal of Phase I.

PHASE II: This phase will follow through to develop a smooth integration of the sub-tools and associated data bases (e.g., subsystems) that support a fully developed ready to go computerized conceptual design tool. Several classes of military aircraft shall be demonstrated (fighters, transports, bombers). A user instruction manual shall be a part of the final report. Hypersonic, airships and rotary wing design cases are not included in the present scope of the effort.

PHASE III DUAL USE APPLICATIONS: Applications include USAF and other service aircraft, and also commercial and general aviation aircraft. The tool shall be able to handle new designs or legacy aircraft modifications. The tool should be modular to enable learning: technology variations, special design cases, updates in procedures.

REFERENCES:

1. Nicolai, L.M., and Carichner, G.E., "Fundamentals of Aircraft and Airship Design, Volume I – Aircraft Design," AIAA Educational Series, 2010 Version.

2. Vehicle Sketch Pad, http://openvsp.org/blogs/announcements/2012/12/08.

3. “Weight and Balance Data Reporting Forms for Aircraft, Part I Group Weights Statement," Mil-Std-1374A (Form 380-U-1).

4. Smith, H.K., and Burnham, R., "The Outside has to be Bigger than the Inside," AIAA-80-0726.

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KEYWORDS: fixed wing aircraft, conceptual design, aerodynamics, structural airframe, propulsion integration, multidisciplinary design optimization (MDO)

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AF141-084 TITLE: Radiation Model Development for Combustion Systems

KEY TECHNOLOGY AREA(S): Air Platforms

OBJECTIVE: Development of physics-based engineering models and corresponding validation procedures as well as associated modules/libraries for radiation heat transfer prediction in combustion systems of relevance to the Air Force (AF).

DESCRIPTION: Advanced physics-based modeling and simulation (M&S) tools are playing an increasingly important role in the design of high-performing combustion devices for AF propulsion systems such as rockets, gas turbines, and scramjet combustors. The prediction of engine performance, reliability, and lifetime typically requires the use of coupled multiphysics models. Among relevant physical phenomena, radiation becomes increasingly important at elevated engine working temperature and pressure, especially applicable to large-scale scramjet (e.g., 10X) and high-pressure liquid rockets. Two major impact areas of radiation are 1) combustion process that is crucial to performance and 2) thermal management that is critical to structural design and engine weight [1,2]. Inclusion of radiation heat transfer models that are properly coupled with the turbulence and combustion are critical in engine M&S tools.

This topic concerns the development of physics-based engineering radiation models for relevant regimes covering high-pressure (>100 atm) and high-speed (supersonic/hypersonic) turbulent reacting flow conditions. This effort will take advantage of recent, state-of-the-art developments in fundamental radiation algorithmic approaches such as those supported by AFOSR and other agencies. The starting point of the effort requires an evaluation of the existing models, including their fundamental assumptions with respect to AF applications. The effort is interested in innovative, sufficiently accurate, and efficient models and procedures for 1) spatial integration of the radiation transfer equation (RTE), such as other spatial integrations based on spherical harmonics, discrete ordinates, zonal methods, Monte Carlo or similar methods [3]; 2) spectral integration dealing with the complex spectrum of hydrocarbon combustion products relevant and important to AF propulsion systems; and 3) coupling between spatial and spectral integrations. The models are expected to operate within a Reynolds-Averaged Navier-Stokes or a large eddy simulations solution procedure. Related approaches that incorporate the effects of turbulence-radiation interactions as well as radiation-chemistry coupling [4] are also of interest. In addition, radiative properties of soot and the effects of carbon deposits on chamber walls are relevant [5]. An additional area of interest is solution procedures to determine the state of the flow from emission and absorption measurements [6]. In all cases, the models should be capable of operating efficiently in a distributed computing environment. Model predictions should be validated versus relevant data being obtained by related AFOSR and/or AFRL programs. Reacting boundary layers with injected liquid and gas hydrocarbon fuel coolant films are of particular interest. Model development should be carried out in a modular fashion through the specification of standardized application programming interfaces (APIs), which would enable the models to be available as plug-in libraries for computation fluid dynamics (CFD) codes of relevance to the AF and its contractors.

PHASE I: Evaluate current radiation modeling assumptions and define validation procedure for their respective use in AF applications including regimes associated with high speed and high pressure. Demonstrate the capability of radiation-turbulence-combustion models for AF relevant propulsion systems. Develop a strategy for well-characterized and generalized interfaces to facilitate module integration.

PHASE II: Further develop/enhance the radiation transfer model capability, including spectrally varying radiation properties and high-pressure regimes. Perform detailed validation for test cases of relevance to the AF. Demonstrate the modular approach for the models in candidate CFD code or codes of relevance to the DoD.

PHASE III DUAL USE APPLICATIONS: Radiation transfer phenomena are of key relevance to the performance of military propulsion systems, including rockets and gas turbines, and to nonmilitary systems such as space launch systems, aircraft engines, land-based power systems, and automotive engines.

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2. Crow, A., Boyd, I., and Terrapon, V., "Radiation Modeling of a Hydrogen Fueled Scramjet," *Journal of Thermophysics and Heat Transfer*, Vol. 27, pp. 11-21.

3. Modest, M., "Radiation Heat Transfer," Third Edition, Academic Press, 2013.

4. Wu, Y., Haworth, D.C., Modest, M.F., and Cuenot, B., "Direct Numerical Simulation of Turbulence-Radiation Interaction in Premixed Combustion Systems," Proceedings of the Combustion Institute, Vol. 30, 639-646, 2005.

5. Charest, M., Groth, C., and Gulder, O., "Effects of Gravity and Pressure on Laminar Coflow Methane-Air Diffusion Flames at pressures from 1 to 60 atmospheres," *Combustion and Flame*, 158 (2011), pp. 860-875.

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KEYWORDS: radiation transfer, radiation-turbulence interactions, radiation-chemistry interactions

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AF141-086 TITLE: Lightweight Detachable Roll Control System

KEY TECHNOLOGY AREA(S): Nuclear Technology

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US

Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop and validate a lightweight, detachable roll control system design that can be integrated with a solid rocket motor and successfully control the motor's spin rate.

DESCRIPTION: The current Minuteman III (MM III) guidance system requires the vehicle to minimize the spin rate by utilizing a roll control system. The roll control system itself is relatively large and heavy, which influences the design of the overall motor. The current roll control system is only on the Second and Third Stage motors due to the motors having single, fixed nozzles. The First Stage motor has four nozzles, and thus has roll control capability and no need for an additional roll control system. However, the future upgrade/replacement motors for all three stages will most likely contain single flex-seal nozzles due to the direction the Solid Rocket Motor (SRM) industry has progressed. The SRM industry has been driven towards this nozzle configuration to minimize cost and maximize performance while still being able to control thrust vectoring. Additionally, the SRM industry has no high demand need to control the motor spin rate on their commercial motors because the current guidance technologies that they use are not affected by spin rate. The MM III guidance system on the other hand is still affected by spin rate until it can be replaced by an updated guidance system. The MM III guidance system will get upgraded in the future, but it is likely not to occur before the current MM III motors are upgraded/replaced. This means that the new SRMs replacing the current MM III motors will need to still have a roll control system to control the motor's spin rate. Since the current roll control system is quite bulky, it would be advantageous to have a small, lightweight, simple roll control system for SRMs with single, flex-seal nozzles. It will also help if this system was separate from the SRM and easily removable. This way once the MM III guidance system is upgraded, the roll control system can be taken off from the SRMs already fielded. The process of placing the roll control system on the SRMs can also then be skipped on those motors that have yet to be built or placed in the field. This capability will allow for easier life maintenance and a lower life-cycle cost of the SRMs.

PHASE I: Create a conceptual design for a detachable, lightweight roll control system. Demonstrate the feasibility of the conceptual design. Identify the required control authority, mechanical interfaces, components, and overall system architecture and demonstrate feasibility through simulation, analysis, or other means.

PHASE II: Refine conceptual design completed in Phase I SBIR, include impacts to current weapon system. Validate design and critical technologies by appropriate methods including but not limited to building a sub-scale prototype along with companion simulation and analysis.

PHASE III DUAL USE APPLICATIONS: Detachable, lightweight roll control system could be applicable to rocket motor use for those organizations who wish to go with a less expensive guidance system. The detachable, lightweight roll control system could be used as a replacement in the future upgrade/replacement motors for the MM III.

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KEYWORDS: Lightweight, Detachable, Roll Control, Solid Rocket Motor, Spin Rate, Flex-seal Nozzle

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AF141-087 TITLE: Additive manufacturing of Liquid Rocket Engine Components

KEY TECHNOLOGY AREA(S): Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop and demonstrate additive manufacturing processes for low-rate production of highly complex liquid rocket engine components.

DESCRIPTION: Manufacturing process development for rocket applications poses significant technical challenges due to the low production rate, the high complexity of the parts, and the harsh environments in which the parts must operate. The typical production rate for liquid rocket engines (LREs) is typically in the 10’s per year. This means typical assembly line or casting-type processes with dedicated machinery are likely to be cost inefficient. Additionally, these parts are typically very complex with the need for precision shapes, tight tolerances, and high repeatability in order to ensure identical engine-to-engine performance. Currently, designers must make compromises in the design of components such as impellers and inducers that have highly complex internal flow geometries that would be difficult to repeatedly and cost effectively manufacture at low production rates with current processes. These challenges do not lend themselves to traditional manufacturing options. Various components within the engine can be subject to very low temperatures (as low as -253°C if Liquid Hydrogen propellant is being used) or very high combustion temperatures (>2000°C). Pressures can range up to 10,000 psi.

Considering these challenges, the development and application of additive manufacturing (AM) are highly desired due to the potential to increase the performance and affordability of rocket propulsion. These features are critical to the advancement of space access and DoD missile programs. One of the advantages of AM is precisely that it can be used for low production rate components since it does not require time-consuming and expensive setups and the machine can easily be reconfigured to produce different parts. In addition, the actual time needed for machining a part can be much shorter than with conventional machines. In some instances, the manufacturing time has gone from weeks to days. The relevant Phase III IHPRPT goals are 100% increase in thrust to weight ratio and 35% reduction in hardware cost over baseline. The development effort should demonstrate significantly shortened lead times for small number of parts while reducing part weight and cost. This needs to be accomplished without sacrificing tolerances and maintaining acceptable surface finish.

Development efforts using additive manufacturing are anticipated to provide significant enhancement over existing domestic and foreign state-of-the-art materials processes. To increase the probability of successful transition to Phase III demonstration or other application areas, the technology development efforts proposed should leverage existing capability and rocket technology development efforts to the maximum extent possible.

PHASE I: Demonstrate feasibility & benefits of additive manufacturing in terms of cost, producibility, performance, etc. Design & possibly build 1 or 2 LRE components, including coupons for mechanical & flammability properties testing, with typical materials: Cu-alloys, Ti-6Al-4V, Monel. Discuss surface finish attainable & impacts to performance as well as potential non-destructive inspection techniques.

PHASE II: Finalize process development for one or more materials. Confirm process by both fabricating test articles for property determination and prototype LRE component of the same size, shape, and complexity as advanced LRE parts. If possible, test built parts at representative LRE conditions. Deliverables: Report of process development and property validation, detailed plan for fabrication process, prototype LRE component, marketing for Phase II Dual Use Applications, test results if applicable.

PHASE III DUAL USE APPLICATIONS: This effort supports current and future DoD space launch applications. It will also support commercial and NASA space launch vehicle development.

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KEYWORDS: Additive Manufacturing, Selective Laser Manufacturing, Electron Beam Melting, Liquid Rocket Engine

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AF141-088 TITLE: Lowest Lifecycle Cost (LLC) Expendable Launch Vehicles

KEY TECHNOLOGY AREA(S): Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Identify and validate high payoff LLC propulsion technologies that are applicable to space launch and large ballistic missile vehicle applications.

DESCRIPTION: Current expendable launch vehicles are designed using an optimum performance methodology. However, there have been numerous studies and technology demonstrations that suggest designing to minimum cost may have life cycle cost advantages over a performance optimized expendable launch vehicle. Performance optimized launch vehicles tend to maximize their payload mass fraction, or conversely, minimize their Gross Lift-Off Weight (GLOW) for a given payload launched into its intended mission orbit. Performance optimization requires high efficiency propulsion and corresponding high propellant mass fractions. These designs can be complex and have high manufacturing costs. On the other hand, LLC strategies weigh the performance advantages of highly optimized systems with simpler designs that have lower manufacturing costs but a larger GLOW. It should be noted that this SBIR topic is interested in proposals which can support existing National Security Space (NSS) payload weights and orbital requirements which can exceed 25,000 lbs to Geosynchronous Orbit (GEO).

The classical optimum performance methodologies have been demonstrated in multiple past designs. However, the simpler design/lower performance strategies have not been implemented in great detail. There are two philosophies in which these design configurations can be implemented. A traditional low-cost design philosophy is to utilize a pressure-fed system to meet requirements. While simpler pressure-fed strategies have appeal, they have significant technical obstacles to overcome. Namely, the biggest technical challenge is to successfully demonstrate a high thrust, lower chamber pressure engine with manageable combustion stability margin. Additionally, large diameter, high strength to weight, cryogenic compatible pressure-fed tanks are also a key technology, allowing realistic management of the vehicles GLOW and related manufacturing costs. Finally, a compact and cost effective high performance propellant tank pressurization system is critical from a scalability and reliability standpoint. Furthermore, high performance pressurization systems that can demonstrate working fluids other than helium are of key importance because helium is a dwindling non-renewable strategic resource. Finally, the increased size of the system may result in higher costs because of the need for additional engines.

A more recent low-cost philosophy is to apply LLC principles to classical performance-optimized pump-fed liquid propulsion components. This approach recognizes that modern launch vehicle design has evolved based on solving a myriad of conflicting physical and system engineering realities. As a result, this technique decomposes traditional pump-fed propulsion systems and examines where targeted technology insertion can simplify the engines design, manufacturing and operational requirements. While both traditional and more recent strategies primarily target engine chamber pressure as a first order cost driver, the latter approach has more latitude than traditional low-cost designs in preserving higher engine operating pressure under a given development program. Therefore, this approach enjoys added design flexibility in managing the combustion stability margin of the thrust chamber and/or preburner assemblies as well as maintaining sufficient throttle in the system in order to minimize payload acceleration.

Within this SBIR, it is expected that organizations will explore pressure fed and/or pump-fed low-cost propulsion technologies. It is acceptable to apply different LLC propulsion strategies to individual launch vehicle stages (e.g., mix and match pressure and pump fed stages). In order to maintain similarity in approach and to ensure that payloads meet NSS requirements, offerors are asked to utilize reference launch system to support initial payload requirements of 30,000 lbs to Low Earth Orbit (LEO) with a pre-defined modular growth path of 60,000 lbs payload that avoids new engine developments. These payload requirements are only intended to demonstrate vehicle scale requirements.

For the reference vehicle, a Technology Development Plan/Technical Roadmap will be developed that shows: 1) critical component traceability, 2) a prioritized risk reduction strategy, 3) test and qualification requirements and strategy, 4) estimated total cost and schedule for Phase II and Phase III risk reduction activities. Assume in the Technology Development Plan that Phase II is dedicated to high risk subscale component(s) testing and Phase III is dedicated to either subscale flight demonstration or full scale component(s) ground testing (i.e., contractor defined). Present the conceptual LLC launch vehicle and Technology Development Plan (Items 1-4 above) to the government for review.

PHASE I: Propose a Technology Development Plan/Technical Roadmap for a Conceptual reference launch system which utilizes a low cost design process. Describe how this concept will generate Lowest Lifecycle Cost (LLC) design in comparison to performance optimized solutions. Identify technologies that are key cost/performance drivers and those that are highest risk.

PHASE II: perform risk reduction testing as identified in the Technology Development Plan. Perform detailed design, manufacture and test of identified high payoff/high risk subscale component(s). Use test data to update the Phase I conceptual reference LLC launch vehicle to a mature conceptual design level.

PHASE III DUAL USE APPLICATIONS: Develop and demonstrate a low cost propulsion technology which will result in a LLC launch vehicle. This will include a combination of development work, component testing, and potentially system demonstrations.

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KEYWORDS: Lowest Lifecycle Cost Design, Liquid Rocket Propulsion, Pressure-Fed, Pump-Fed, Liquid Rocket Combustion Stability

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AF141-089 TITLE: Electric Propulsion for Orbit Transfer

KEY TECHNOLOGY AREA(S): Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop innovative high-power, long lifetime electric propulsion thrusters with wide throttle range for orbit transfer of DoD space assets.

DESCRIPTION: Electric propulsion (EP) has the capability to greatly enhance the in-space maneuverability and payload capacity of spacecraft compared to liquid chemical propulsion. However, current electric propulsion devices do not provide enough thrust to perform some time critical maneuvers. For example, advanced military communications satellites such as Advanced EHF use a combination of chemical and high-power Hall thrusters for the LEO to GEO orbit transfer. A satellite utilizing all electric propulsion would provide greater fraction of delivered payload than a chemical system. However, increased duration in the belts with state-of-the-art EP will have a detrimental impact on spacecraft mission lifetime due to radiation damage to the solar arrays and payload electronics. Research on innovative high power, high thrust, and inherently long lifetime thrusters is required to realize the full advantages of electric propulsion for DoD missions.

Advanced electric propulsion technology with high efficiency over a wide range of specific impulse and power levels would enable high thrust operation for rapid transit through the belts, and high specific impulse for high efficiency from the belts to GEO. This all electric propulsion system eliminates the need for chemical thrusters and the mass of chemical propulsion propellant, thereby maximizing payload to orbit and minimizing propulsion system complexity.

This solicitation seeks research on electric propulsion technologies capable of achieving specific impulse from 1000-2000 seconds with total thruster efficiency greater than 60% and thruster specific power less than 1 kg/kW. Proposal solutions may be either ideas for improving existing thruster technology or the development of new concepts. A representative power level for this technology is 5-10 kW per thruster, though demonstrations may be conducted at different power levels to accommodate cost-effective research activities. The full propulsion system (thruster, power processing unit & propellant feed) should define a clear path for transition to military space applications in the proposal. The thruster technology should be capable of supporting a 15-year mission in Geosynchronous Earth Orbit (GEO) or Medium Earth Orbit (MEO) and 5 years in Low Earth Orbit (LEO) after ground storage of 5 years.

PHASE I: Perform proof-of-concept analysis and experiments that demonstrate the feasibility of the compact low mass, high performance propulsion concept.

PHASE II: Measure performance and plume characteristics of breadboard hardware to demonstrate program goals for compact low mass thruster. Breadboard hardware will be evaluated on thrust stands at AFRL, and achieve TRL 5 at the end of Phase II activities. Deliverables include breadboard hardware, preliminary cost analyses, and full performance analysis with comparison to state-of-the-art EP.

PHASE III DUAL USE APPLICATIONS: The high-power thruster will be useful for geosynchronous orbit transfers for large communications satellites and large military spacecraft that will perform a variety of critical missions. This technology enables dual launch manifest and can be used for commercial comsats and space tug.

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KEYWORDS: Electric Propulsion, High Power, High Delta-V, Responsive, Orbit Transfer

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AF141-091 TITLE: Physics-based modeling of solid rocket motor propellant

KEY TECHNOLOGY AREA(S): Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop innovative physics-based models facilitating the accurate prediction of solid rocket propellant behavior with varying environmental boundary conditions.

DESCRIPTION: With the need to sustain the existing Air Force Solid Rocket Motor (SRM) fleet for increasingly long times, accurate prediction of SRM capabilities becomes crucial. The paradigm is to predict the behavior of SRM propellant and the propellant, liner, insulation (PLI) using empirical curve-fitting expressions extrapolated out to the desired conditions. The above method leads to large potential errors (~55%) in predictions for history dependent materials such as polymers. Hiu describes how elastomeric polymers fail earlier than anticipated due to rate dependent bond rupture [1]. It would be prohibitively expensive to test enough samples with different environmental exposure histories to give adequate confidence in these empirical methods. Thus a physics-based modeling approach is desired where all of the parameters have physical meaning and may be linked to boundary conditions (typical strategic environment 60-80 degrees Fahrenheit with moderate humidity). A physics based model will improve our ability to predict if a specific motor is good or bad based on conditions it has experienced. Topics of particular interest are the connection between polymer morphology/cure with mechanical properties, and cumulative damage including the potential for self-healing, possibly by competing chemical mechanisms [2]. Models developed in this area have the potential to significantly improve our design and analysis capabilities; the PLI in particular is thought to be one of the largest sources of error in structural analyses. The models would also enable the long-desired capability to design an SRM propellant system a priori for a specific application. The proposed model should be computationally tractable on an engineering workstation or small cluster. Supercomputers are not practical, as these models are intended for frequent use in the design and structural/health analysis of SRMs. The overarching goal is to reduce uncertainties by a minimum of 10% in modeling the propellant and/or PLI leading to higher confidence in the reliability of the SRM fleet. Innovative solutions that can focus on high impact parameters to reduce uncertainty are highly sought-after. Solutions should have a strong backing in: the fundamental material physics and chemistry in addition to adherence to engineering principles; previous research and development; scientific literature; and cost-benefit analysis. The successful proposed Phase I will develop the necessary theoretical framework for a SRM propellant model illustrating that all parameters have a physical basis. Additionally the phase I should address the computer requirements for the model to be computationally tractable, and should estimate the anticipated accuracy. The proposed solution shall be affordable and usable. Usability shall take into account operability, sustainability, supportability, interoperability, modularity, and reliability. The proposed system should leverage standards-based communication and open-source software wherever possible. Partnership(s) with a current Department of Defense prime contractor(s) is highly desired, such a relationship would aid in the refinement and implementation of the proposed model into existing SRM analysis codes. The Phase II will include programming and implementation of the theoretical framework on the proposed computer system. It will also include a validation and verification effort based upon available scientific literature. Due to the ubiquitous usage of polymeric materials and the strong grounding in physics these models should lend themselves to modification for a myriad of relevant commercial usages, e.g. polymer manufacturing, fatigue of plastic structures, etc.

PHASE I: Develop a theoretical framework for physics-based models for SRM propellant and/or PLI. Illustrate the potential benefits. Determine required computational resources and how the code would interface with common commercially available structural analysis software.

PHASE II: Program theoretical framework on proposed computer system ensure it is able to interface with structural analysis software. Verify and validate the developed model using relevant data from scientific literature. Illustrate expected benefits and average runtime. Demonstrate computer model to customer and deliver software code along with a user's manual.

PHASE III DUAL USE APPLICATIONS: Military application: Current and future ballistic missiles and space launch applications, supporting the design and analysis of SRMs. Commercial application: Manufacturing of polymers, structural analysis of polymeric materials, potential to extend models to encompass composite systems.

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KEYWORDS: solid rocket motors, physics-based models, polymers, physics, chemistry, solid propellant, degradation mechanisms, cure mechanisms, health monitoring

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AF141-092 TITLE: Advanced Integrity and Safety Assurance for Software

KEY TECHNOLOGY AREA(S): Nuclear Technology

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OBJECTIVE: To develop new analysis tools and techniques for safety verification and validation of software embedded in or controlling strategic systems.

DESCRIPTION: Software controlling U.S. nuclear weapons must have the highest possible assurance of safety and integrity. The essence of nuclear safety certification is an intensive review, verification, and validation of developed software, starting with requirements and ending with integration and regression testing (new software is generally integrated into an existing code base). As the nuclear community, including ICBM Minuteman III, military nuclear weapon systems, DOE, Sandia and other government/military organizations with nuclear critical software applications, continues to evolve, innovations in processes/tools used for mission safety testing are needed to prevent threats from malicious code that could cause unintended nuclear consequences. Standard processes and tools to assure the correctness, safety, and integrity of such software are needed to maintain the highest level of safety.

State-of-the-Art Description - Currently, each government nuclear operational system uses separate processes/tools for certifying nuclear critical software applications before fielding. For instance, the ICBM Program Independent

Verification & Validation (IV&V) efforts are governed in accordance with Air Force Manuals (AFMAN) 91-119 and 91-118; however, these publications are not used by the DOE. Each government (DOE, SNL) and military (Navy) organization with nuclear safety requirements uses similar but separate IV&V processes/tools when certifying nuclear critical software applications.

This SBIR proposes an innovative approach to standardize the processes/tools used to perform mission safety testing of nuclear critical software applications. The SBIR proposal goal includes collaboration between DOE/government/military organizations in order to benefit from standard V&V processes and tools. The SBIR will be used to standardize process/tools innovations that account for modern command/control/communication/computers across a network that is potentially vulnerable to cyber-attack due to modern software-processing architectures. The SBIR also provides for innovative approaches to perform verification & validation of complex code development tools, such as compilers, before being used to develop operational nuclear critical software applications. SBIR processes and tools developed for software testing can also be used to standardize, improve and share testing methods among all government/military software V&V testing organizations outside of the nuclear community.

Standardized tools used for nuclear weapons software surety certification testing shall consist of static and dynamic analyzers, CPU simulators, and binary file comparisons, and configuration management. Testing processes will be defined to perform both nominal and off-nominal conditions during execution of the software application. Static source code analyzers will be used to search for malicious code and logic coding errors. Runtime simulator tools will be used simulate operational environments and software application response to incorrect or malicious data inputs.

The tools and techniques developed under this research should provide the following capabilities:
1. Tracing from high-level requirements statements (called "Nuclear Safety objectives") to lower-level requirements (called "Nuclear Safety requirements"), detailed requirements, and into the implementation. Such traceability must be bidirectional and accommodate changes in a manner which enables complete control, and retrospective analyses.
2. Complete structural analysis of code including ability to identify the setting and using of all program variables, as well as persistently stored values, tracing of execution paths, and development of test cases to trigger execution of specific code paths.
3. Testing tools to achieve complete branch and condition coverage.
4. Static analysis to check for both conformance with secure coding standards and the presence of malicious code.
5. Regression testing tools.
6. Dynamic analysis tools including simulation of a VAX and a MIL STD 1750A microprocessor with the ability to set watch points and breakpoints.
7. Formal verification tools for both temporal and non-temporal analysis. This includes the ability to show the translation (even if performed manually) between natural language requirements and formally stated requirements.
8. Other analysis techniques offered by proposers for the purposes of assuring integrity and safety.
9. Verification, validation, and testing management tools to assist in automation of the Nuclear Safety Cross Check Analysis (NSCCA) process.

Proposals that describe solutions utilizing existing tools, or new tools, or both, to achieve these capabilities in a single integrated framework are encouraged. Proposals that include demonstrating the tool sets using representative example systems with source code in Ada, C, or FORTRAN (5-10 KSLOC) are particularly encouraged. Items 3 through 27 in the attached reference list are examples of the state of the art of high integrity and safety critical software development in the following areas: Standards, requirements formulation (including decomposition and tracing to the design), formal methods, behavioral modeling and model checking, code generation, model checking, architectural design languages, integrated environments spanning the development process from model based design through code generation, static analyzers, software test automation (including model-based testing for automated test case generation and test drivers for regression testing). These are representative and by no means intended to limit the proposed approach.

PHASE I: Demonstrate the feasibility of a methodology and associated tools to NSCCA verification.

PHASE II: Full development (and testing) of the tools and demonstrate the methodology proposed on realistic representative test cases.

PHASE III DUAL USE APPLICATIONS: DOE/DoD organizations can benefit from IV&V processes & tools developed for ICBM program s/w testing. The tool set & methods developed can be used for safety critical s/w in auto, civil aviation, medical, & industrial control in accordance w/standards such as RTCA DO 178C, IEC 61508, & SAE 27272.

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KEYWORDS: safety critical systems, software safety, software verification, high integrity systems, software testing, Nuclear Safety Cross Check Analysis, NSCCA

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AF141-093 TITLE: Development and Verification Tools/Processes for ASICs and FPGAs

KEY TECHNOLOGY AREA(S): Nuclear Technology

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual

use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Innovative solutions for providing U.S. domestically-owned ASIC/FPGA testing processes/tools capabilities to certify against malicious code/electronics design that could cause unintended consequences from nuclear operational applications.

DESCRIPTION: Programmable Logic Devices, such as FPGAs and ASICs, controlling U.S. nuclear weapons must have the highest possible assurance of safety and integrity. Top-level safety requirements, called Nuclear Safety Objectives (NSOs), for such devices are set forth in two publications, AFMAN 91-118 and 91-119 (see references). Additional specific functional and non-functional requirements are developed for the specific devices at the start of the development. A specialized process must be used for intensive verification of system safety against these and other derived requirements.

Examples of activities under this process include:
As ASICs and FPGAs grow increasingly complex; the nuclear surety certification process must innovate to provide modernized processes and tools and to assure their correctness, safety, and integrity to maintain the highest level of safety.

The RTCA DO 254 standard (see references) developed for complex programmable logic devices in avionics applications has also been used in other applications and is an industry and certification authority accepted approach for assuring conformance with safety requirements. For nuclear weapons applications, the anticipated assurance level would be System Level A. The objective of this research is to define a high assurance process and associated tool set to provide this assurance.

The specific goals include:
1. A gap analysis of the RTCA DO 254 standard against AFMAN 91-118, 91-119, AFI 91-101 requirements and recommendations for changes (if any).
2. Definition of a specific set of process objectives and verification criteria for device assurance.
3. Identification of specific tools or definition of methods to actualize the process. It is anticipated that such tools will include:
a. Requirements traceability
b. HDL tools (VHDL, Verilog, or SystemC) for design and testbench synthesis
c. Functional simulation
d. Logic synthesis
e. Logic equivalency checking
f. Place and route
g. Worst-case timing analysis
h. Other special analytical capabilities

Proposals that describe solutions utilizing existing tools, or new tools, or both, to achieve these capabilities in a single integrated framework are encouraged.

PHASE I: Demonstrate the feasibility of a methodology and associated tools to Nuclear Safety Cross-Check Analysis (NSCCA) verification.

PHASE II: Full development (and testing) of the tools and demonstrate the methodology proposed on realistic representative test cases.

PHASE III DUAL USE APPLICATIONS: Broaden tool for safety critical software in auto, civil aviation, medical and industrial control in accordance with standards (RTCA DO 254). Processes/tools may also be used to protect against malicious programming of ASIC/FPGA devices used by commercial industry and to detect counterfeit parts.

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2. AFMAN 91-119 , Safety Design And Evaluation Criteria For Nuclear Weapon Systems Software, 1 Feb 1999, available online at: http://afpubs.hq.af.mil.

3. RTCA DO-254/ED-80 (Design Assurance Guidance for Airborne Electronic Hardware), RTCA, Inc.1828 L Street, NW, Suite 805Washington, D.C. 20036 U.S.A (202)833-93.

KEYWORDS: safety critical systems, ASICs, FPGAs, safety critical, verification, validation, formal methods, testing

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AF141-094 TITLE: Algorithm Based Error Estimation & Navigation Correction

KEY TECHNOLOGY AREA(S): Electronics and Electronic Warfare

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop and demonstrate an algorithm-based scheme that improves navigation accuracy and responsiveness of inertial-based navigation systems.

DESCRIPTION: The U.S. Air Force would like to explore more accurate and more robust navigation capabilities for strategic systems. The strategic system is heavily dependent on the Inertial Measurement Unit (IMU) for strategic system navigation since there is limited or no external aiding. Whereas the Navy's SLBM uses a star tracker to aid its inertial navigation system, the Air Force ICBM mission relies entirely on autonomous inertial navigation. The Air Force would like to explore improving accuracy without having to implement an external aiding scheme to the ICBM navigation, guidance and control system. Since computing power has drastically increased over the past decades, the Air Force is interested in complimenting strategic grade inertial sensors with advanced navigation algorithms to improve performance during flight. With the exclusion of external aiding, the current and future hardware must have a complimentary suite of navigation algorithms to ensure the strategic vehicle will meet the desired terminal conditions.

The Air Force is interested in algorithmic solutions that improve the capability of existing inertial measurement units and inertial instruments while taking advantage of modern computing capability. Such a capability would be robust, accurate, low to moderate bandwidth, novel, and based upon dynamic constraints, statistical estimations or other non-heuristic schemes. It would increase accuracy and responsiveness for both the Intercontinental Ballistic Missile (ICBM) and CM systems.

Commercialization potential: DoD applications include the ICBM network and CM systems. Commercial applications include any commercial device that has an IMU where a more accurate navigation ability is desired.

PHASE I: Develop algorithms for an IMU-based navigation system that addresses nonlinear, non-Gaussian error terms encountered during system flight. Describe the trade-offs, and develop concepts of operations for different alternatives developed. Prepare a report on the findings and develop a plan to demonstrate the navigation algorithms in a relevant simulation environment.

PHASE II: Develop a demonstration of the algorithms using realistic IMU models, demonstrating the ability of the algorithms to accurately navigate an ICBM or CM (without updates) to within a prescribed set of targeting conditions. Evaluate the feasibility of transitioning these capabilities into flight capable hardware, including integration into different missile systems.

PHASE III DUAL USE APPLICATIONS: This technology, if realized, would be of obvious immediate benefit to both DoD and commercial IMU users operating in a GPS-denied environment, such as buildings.

REFERENCES:

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7. Anton J. Haug; Bayesian Estimation and Tracking: A Practical Guide; Wiley & Sons, Inc. 2012

KEYWORDS: navigation, algorithm, error correction, statistical, dynamic constraints, Bayesian, nonlinear estimation, inertial based navigation, strategic system navigation, GPS denied navigation algorithms, nonlinear navigation schemes

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AF141-096 TITLE: Radiation Hardened Cache Memory

KEY TECHNOLOGY AREA(S): Materials / Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop a power efficient, high speed, radiation hardened memory device suitable for long term space missions by using carbon nanotubes (CNT) or other innovative materials and processes, (e.g.graphene), processes (3-D), & architectures (memristive).

DESCRIPTION: In order to meet projected growth in broadband military satellite communications, future generations of payloads will be required to process the waveform at a significantly higher rate. Unacceptably long memory cycle times can diminish the performance of payload front-end processing by adding undesirable time lags and leading to poor overall payload performance. To address this concern, the Air Force seeks a new generation of radiation hardened cache memory devices capable of allowing the central processing unit (CPU) to operate with minimum memory cycle time by avoiding the introduction of wait states. Before the next generation cache memory is viable for insertion into a space mission, the materials and/or fabrication process must be proven reliable, affordable, and of a density and performance that makes the memory component attractive as an alternative to the current generation of space memory. In particular, the cache memory device must be shown capable of meeting the timing constraints of an emerging generation of space qualified general purpose and special purpose processors, while withstanding the full range of natural and manmade threats encountered in a long term, geosynchronous space environment.

The purpose of this topic is to support research into innovative materials and/or processes leading to a high speed cache memory device. In order to better cope with the complex radiation environments, spacecraft electronics are often implemented in a “radiation-hardened” form that is three or more generations behind the contemporary commercial state-of-the-art. Since spacecraft are furthermore power-constrained, the effects of these performance penalties are compounded by an inability to field enough of the slower components to mitigate this gap. Component selections are limited, especially for specialty memories, which stand-alone cache (e.g., “level 2” or “L2”) are considered to be. Despite the compelling benefits that effective cache architectures can provide to general- purpose computation, much less attention is paid in developing these options as in developing the processor or FPGA components that might take advantage of them.

In this topic, we seek creative innovations that will give us better options for larger, lower-power, and higher-performance (measured in reduced average access delays from processors) memory components that can either augment a traditional memory hierarchy or effectively collapse it (for example, by having a L2 cache large enough to fit most problems of interest without having cache miss events). The answer need not be confined to a traditional component solution, but can involve new interpretations of hybrid memory, stacked components (for example, using through-silicon vias), even possibly three-dimensional architectures that more effectively collocate processing resources with larger, more efficient memory structures. It may be advantageous to examine new architectural approaches, such as memristors, and materials, such as carbon nanotubes, phase-change materials, or grapheme. Along with these notions of better memory technologies, we must overlay the considerable constraints of working in space. Before the next-generation cache memory is viable for insertion into a space mission, the materials and/or fabrication process must be proven reliable, affordable, and of a density and performance that makes the memory component attractive as an alternative to the current generation of space memory. In particular, the cache memory device must be shown capable of meeting the timing constraints of an emerging generation of space-qualified general purpose and special purpose processors, while withstanding the full range of natural and manmade threats encountered in a long-term, geosynchronous space environment. And of course, the cost of modern microelectronics fabrication provides a challenge as great as most of the other technical barriers.

Example goals include access time < 3 ns, density >> 16 Mbits, simple voltage supply (e.g., < 3.3V or configurable power rail), extended operating temperature range (-40 to +80 degrees C), 1 Mrad(Si) total dose radiation tolerance, and Single Event Effect (SEE) immunity to 60 MeV. Commercial applications include consumer electronics, auto, and commercial space.

PHASE I: Investigate design architecture trade-offs and process integration issues concerned with developing radiation-hardened cache memory. Establish feasibility of a next-generation cache concept through as many methods as practical, to include simulation models, reference designs, and prototyping (may be useful in approaches involving advanced materials and devices).

PHASE II: Develop one or more prototypes and characterize for access time, radiation tolerance from total dose and single event effects, storage density, and power consumption. We encourage offerors to seek partnerships with suitable semiconductor houses for assistance with fabrication support, along with the sponsorship of aerospace contractors / developers to improve technology transition opportunities.

PHASE III DUAL USE APPLICATIONS: Military applications for radiation hardened cache memory include spacecraft avionics for satellite bus subsystems and payloads. Commercial: Commercial spacecraft can benefit directly from this work.

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1. S. Manne, A. Klauser, and D. Grunwald, "Pipeline gating: speculation"; J. Abella and A. Gonzalez, "Heterogeneous way-size cache," in ICS, 2006.

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KEYWORDS: Cache memory, radiation hardened cache, random access memory, volatile memory, carbon nanotube, cycle time, wait state

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AF141-097 TITLE: Next Generation Rad Hard Reduced Instruction Set Computer

KEY TECHNOLOGY AREA(S): Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop a radiation-hardened Advanced Reduced Instruction Set Computer suitable for use in long-term space missions.

DESCRIPTION: As satellite payload processing becomes more broadly distributed across subsystems, there will likely be an increased need for a new generation of smaller (relative to general purpose processors), more power efficient, radiation-hardened microprocessors of reduced complexity to meet a broad range of payload processing functions such as antenna controllers. Advanced architectures, such as the Advanced RISC (Reduced Instruction Set Computer) Machines (ARMs), are ideal candidates for distributed space processing. For example, ARMs are typically designed for: power efficiency, small circuit board footprint, limited instruction set (which eases the programmer's learning curve), and a relatively small gate count (which reduces hardware complexity and improves reliability). In addition, the extensive commercial use of ARMs has led to a broad assortment of advanced development and debugging tools and the extensive commercial legacy providing failure data to help instill confidence for space mission assurance. The purpose of this topic is to develop a 32-bit, radiation-hardened, space-qualifiable ARM processor that is suitable for long-term space missions. Research under this topic should strive to maintain compatibility with commercial ARM processors to leverage existing software development support, including debugging tools. ARM prototypes developed under this research should also strive to include a full complement of built-in features, including interrupt controller, optimized gate count, power-saving mode, debug capability, 32-bit word length, and fully deterministic timing behavior. Additional goals include immunity to destructive latchup, total ionizing dose tolerance to 1Mrad (Si), Single Event Effect (SEE) immunity to 60 MeV, operating temperature range from -40° C to +80° C, and component reliability consistent with 15-year on-orbit satellite mission life.

PHASE I: Design prototype radiation hardened processor architecture that is low power, within a small circuit board footprint, uses a limited instruction set, and contains a relatively small gate count (such as you find in a ARM architecture), and validate through modeling and simulation.

PHASE II: Fabricate radiation hardened prototype and characterize for all relevant performance metrics including throughput, power consumption, reliability, operating temperature range, and radiation tolerance, including SEE immunity.

PHASE III DUAL USE APPLICATIONS: Military: This research could benefit all military satellite programs requiring power efficient space computing. Commercial: Commercial applications include commercial space, avionics and automobiles.

REFERENCES:

1. Yiu, Joseph, The Definitive Guide to the ARM© Cortex™ – M0, Elsevier Inc. Oxford UK, 2011.

2. Merniz, S.; Benmohammed, M.; "A Methodology for the Formal Verification of RISC Microprocessors A Functional Approach," Computer Systems and Applications, 2007. AICCSA '07. IEEE/ACS International Conference on, pp.492-499, 13-16 May 2007.

KEYWORDS: ARM, space processing, space computer, reduced instruction set, microelectronics, integrated circuit

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AF141-099 TITLE: Power Aware GPS User Equipment

KEY TECHNOLOGY AREA(S): Electronics and Electronic Warfare

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Specific to a ground-based military GPS receiver, develop a power management strategy which is implemented with an intelligent embedded software monitor/control application to balance power consumption against receiver performance.

DESCRIPTION: Modernized military Global Positioning System (GPS) receivers continue to improve in capability, but the demand for increased battery life remains a constant challenge. GPS receivers are developed using application specific integrated circuit (ASIC) devices that are fabricated in advanced submicron fabrication processes. They efficiently integrate multiple microprocessor cores, crypto engines and large acquisition circuits to meet size and power requirements. However, the newer semiconductor processes are now dominated by static power dissipation due to transistor leakage. A common approach is to reduce the power by reducing the position accuracy through various power-down, duty cycle tradeoffs in tracking and acquisition, but the challenge is to find the right mix between power and accuracy to meet the requirements for a given application (e.g., munitions, personnel location and time delivery). Also, military receivers can receive both civil and encrypted codes. There may be time windows where the military codes are not needed and performance modes could be adapted to the exposed RF environments. The objective is to develop an application which implements an intelligent power management strategy and suite of algorithms which trades between power and predictable performance behavior for any receiver. The application should reduce the power required to track encrypted military signals by 50%--typical power consumption for state-of-the-art military receivers is below 1.2W during tracking using 90nm technology.

Research GPS receiver power management techniques which allow for specific optimizations based on various mission scenarios and use cases. The study should define the use cases and define metrics which could be used to measure power and performance with degradation in mission effectiveness. These metrics should relate to receiver performance tradeoffs of critical requirements such as accuracy, Time To First Fix (TTFF), Anti-Spoof, Anti-Jam, as well as military exclusivity. The study should survey and suggest different hardware/software architectures and algorithms that could be implemented to reduce power by design optimization, as well as pulling back on receiver performance, but still maintain mission effectiveness. The study should look to combine these techniques into an application which takes a holistic approach, accounting for mission-specific requirements and use cases while leveraging related software and hardware power optimizations which are common for battery operated products. In addition, the application should have awareness of and leverage on-chip power management enablers, such as power islands, back bias and clock gating.

PHASE I: Research GPS receiver power management techniques which allow for specific optimizations based on mission scenarios and use cases. Define the use cases and define metrics for power and performance with degradation in mission effectiveness. These metrics are receiver performance tradeoffs of critical requirements such as accuracy, TTFF, Anti-Spoof, Anti-Jam, as well as military exclusivity.

PHASE II: Phase II will focus on the simulation, implementation, and benchmarking of the techniques proposed during Phase I. Demonstrate techniques at the architecture and algorithmic level using simulations in high-level languages. Implement the techniques as electronic circuits and software in a suitable hardware-description language using constructs and resources independent of technology. Build prototypes.

PHASE III DUAL USE APPLICATIONS: Enable technology transfer and subsequent research by capturing the innovation techniques developed and demonstrated during Phases I and II. Deliverables should be presented as structured, reusable intellectual property packages suitable for implementation in various ASIC & FPGA technologies.

REFERENCES:
1. u-blox Power Management Application Note: Considerations with u-blox 6 GPS receivers: Document GPS.G6-X-10014-B.

2. US Patent: # 5995042: Spoofer detection power management for GPS receivers, Isaac Newton Durboraw, III, et al.

3. http://www.eetasia.com/ART_8800498402_765245_NT_aa673e92.HTM; Address power management issues in mobiles.

KEYWORDS: GPS, power management, portable, battery, processor, energy, power, efficiency, modernization

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AF141-100 TITLE: Secure Time delivery Military GPS receivers in challenged RF environments using existing wireless infrasructure

KEY TECHNOLOGY AREA(S): Electronics and Electronic Warfare

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop an accurate and secure GPS time-aiding service that considers the time uncertainty from universal time (UTC) of existing commercial and tactical wireless infrastructure.

DESCRIPTION: There are several methods to obtain time through commercial and tactical communication infrastructures; however, the level of trust and accuracy of these mechanisms limit their usefulness for military missions. Investigate alternatives for delivering secured time with highest accuracy to military GPS in tactical environments which leverages existing commercial or military communication infrastructure.

Applications that require synchronization often depend on GPS receivers to provide a source of accurate time. However, there are many situations when time is needed by the GPS receiver itself to reduce the Time-to-First-Fix (TTFF), e.g., when the GPS service is denied due to RF interference. For military receivers, providing coordinated universal time (UTC) between microsecond to millisecond accuracy provides anti-jam robustness by enabling direct acquisition of the military encrypted signals. Given that time is often provided over commercial wireless and tactical wireless communication networks, it is assumed military GPS receivers could be better integrated to leverage this as a “time-aiding” service. The challenge is to identify the various impacts to time transfer accuracy due to inherent limitations of a particular communication waveform, network deployment and equipment design (e.g., latency, clock jitter, protocols, software scheduling, etc.). In addition, for a GPS time-aiding service to be robust for military or public safety applications, authentication mechanisms would be needed to assure the time transfer. Therefore, the objective of this topic is to develop an accurate and secure GPS time-aiding service that considers the time uncertainty from UTC of existing commercial and tactical wireless infrastructure.

Provide a detailed pro/con explanation for each of the wireless waveforms. Recommend an approach that requires the least amount of changes to the wireless waveform and deployment infrastructure while offering the robustness required to time-aid a GPS receiver for military and public safety applications. Explain the ability to scale the approach from a small to large network.

Enable technology transfer and subsequent research by capturing the innovation techniques developed and demonstrated during Phases I and II. Deliverables should be presented as structured, reusable intellectual property packages suitable for implementation in a variety of wireless communication devices

PHASE I: Research existing tactical and commercial wireless waveforms for applicability to support a secure and accurate time transfer. Perform a trade analysis for each communication waveform investigated using metrics to rank application suitability, accuracy, integrity, and cost.

PHASE II: Focus on the simulation, implementation, and benchmarking of the recommended approach in Phase I. Demonstrate the ability of this approach to provide a military GPS receiver with effective time-aiding in the presences of RF interference. Build prototypes.

PHASE III DUAL USE APPLICATIONS: Military: Secure time delivery systems readily implementable in future subsystems. Commercial: There are expected civilian uses.

REFERENCES:
1. 42nd Annual Precise Time and Time Interval (PTTI) Meeting, UTC Time Transfer for High Frequency Trading Using IS-95 CDMA Base Station Transmissions and IEEE-1588 Precision Time Protocol, Michael D. Korreng, EndRun Technologies.

2. Common Time Reference for Naval Systems, NRL/FR/8150--04-10,079.

3. Duffett-Smith, Peter J., Hansen, Paul, "Precise Time Transfer in a Mobile Radio Terminal," Proceedings of the 2005 National Technical Meeting of The Institute of Navigation, San Diego, CA, January 2005, pp. 1101-1106.

KEYWORDS: GPS, time transfer, TTFF, time uncertainty, A-GPS, time aiding, tactical radio, 3GPP, time-aiding

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AF141-101 TITLE: Multi-Processor Array for Multi-Parametric Sensing in Cubesat DoD (or Air Force) Space Missions

KEY TECHNOLOGY AREA(S): Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop a compact multi-processor system to support observation-based Cubesat payloads including single sensor and/or multi-sensor capability.

DESCRIPTION: CubeSats, small modular satellite platforms that range from 1U to 3U size, are becoming highly regarded by both commercial and military organizations that are exploring their use for various applications from surveillance to communication to research missions. Standards-based satellite buses and deployment mechanisms such as the CubeSat and Poly Pico-satellite Orbital Deployer (P-POD) have driven expansion and technology development forward. Small satellites have proven to be very adept at focused tasks and require much lower capital expenditure and development time for both payload and launch tasks in contrast to expensive legacy monolith satellites and their costly launch requirements. Though the cost and development times associated with cubesats are much lower than conventional satellites, their size, weight, and power-constraint (SWaP-C) demands are much more stringent, particularly with regard to onboard processing. This poses a challenge since many of the missions envisaged for small spacecraft involve autonomous surveillance and situational awareness that requires monitoring and fusing widely disparate sensor data streams, as well as performing health monitoring and housekeeping which can tax commonly available embedded processors. While FPGAs are effective for some applications, the development and validation time for a given design can be considerable. Instead, a technology that shows considerable promise in this arena are embedded heterogeneous processor arrays consisting of dozens of identical processors. Such designs are better suited to graceful degradation in the face of radiation damage and also recover better from defective instructions and programming. In addition, such designs have remarkably scalable power consumption given their ability to shut down individual processors selectively or reallocate processors to perform load balancing. While General Purpose Graphical Processing Unit (GPGPU) approaches are the most widespread manifestations of this technology, an increasing number of mobile and embedded systems are proliferating.

This solicitation seeks to develop processing subsystems based on COTS multiprocessor array systems which are capable of performing multi-parametric fusion, orbital propagation, and sensor housekeeping in a cubesat environment. It can be estimated that two thirds of a 3U CubeSat SWaP will be used for power management, attitude control, communications and other basic spacecraft functions. Therefore, the processor array should fit within a small percentage of a 1U design and use a small percentage of the allowed 1.33 kg mass. It should have the capability to survive the LEO space environment for at least two years with a goal of three, operate with significant power constraints with a very low duty cycle or instantaneous power, and have a deep sleep cycle which can be awakened by a significant event of interest and which does not require continuous sensor polling.

PHASE I: Develop a novel multi-processor design for CubeSats to support AF space surveillance missions using multiple sensors for space, ground or ocean observation. Tasks could include developing the technology design, predicting sensor performance w/ the processor array using a simulation or other tools, estimating the mass, volume & power requirements, & presenting methods to mitigate power consumption.

PHASE II: Build a prototype processor array and test it in a representative environment.
• Optimize the power usage design.
• Demonstrate payload operation in a space setting such as thermal vacuum.
• Evaluate operation in a space radiation environment.
• Evaluate measured performance characteristics versus expectations and make design adjustments as necessary to enable full sensor operation.

PHASE III DUAL USE APPLICATIONS: Focus on integrating the technology into potential DoD (or Air Force) CubeSat missions. The technologies developed under this topic can be applied to a variety of commercial, military and space exploration CubeSat missions.

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KEYWORDS: cubesat, payload, processor arrays, multi-processor, embedded systems

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AF141-102 TITLE: M-code External Augmentation system

KEY TECHNOLOGY AREA(S): Electronics and Electronic Warfare

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type

of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Working within the signal definition of IS-GPS-250A, conduct a trade study on suitable EAS signal modulations that are spectrally compatible with M-Code and BFEA and have minimum impact on conventional receiver signal processing techniques.

DESCRIPTION: IS-GPS-250A (1) is an interface specification for an External Augmentation System, also known as a pseudolite (2), that provides a terrestrial source of signals for position, navigation and timing (PNT) purposes. These signals are currently defined to have the same modulation as P(Y)-code but with differing signal structure to facilitate simultaneous reception of both satellite and EAS signals.

In the presence of BFEA signals, any signal with P(Y)-code modulation will be significantly degraded, preventing reliable acquisition and tracking. Since IS- GPS-250A is developed on a P(Y)-code modulation, it is spectrally incompatible with BFEA.

The objective of this study is to investigate alternative signal modulations that would be spectrally compatible with BFEA and with existing M-Code signals. Since IS-GPS-250A is currently being implemented in MGUE (3), the purpose of this study is to examine a modulation within the signal structure defined in IS-GPS-250A that is complementary to existing M-Code signal processing techniques.

The study should examine the impact to M-Code signal reception. The study should also take into consideration any modifications that would need to be made to a typical GPS receiver signal processing chain to facilitate reception of the new EAS signal.

PHASE I: A report that quantifies the tradeoffs of various modulations and signal structures that are spectrally compatible with both BFEA and M-Code (e.g., BOC(10,5), BPSK-R10 offset from L1/L2, BOC(10,1), etc.).

PHASE II: Building from the Phase I design, Phase II will develop an engineering model simulation of the signal space and receiver processing algorithms that will show the impact of the BFEA and M-Code spectrally compatible EAS signal on M-Code EAS signal performance.

PHASE III DUAL USE APPLICATIONS: Military Application: With the inclusion of IS-GPS-250A in MGUE Increment 1, the Phase II applications should enable rapid implementation of a BFEA and M-Code compatible signal in existing receiver architectures. Commercial Application: Will not be available due to national security reasons.

REFERENCES:
1. “IS-GPS-250 Navstar GPS Y-Code External Augmentation System (EAS)/User Equipment Interface,” Global Positioning Systems Directorate, 30 January 2012.

2. “Pseudolites,” B.D. Elrod and A.J. Van Dierendonck, Global Positioning System: Theory and Applications, Volume II, Eds: P. Axelrad, J.J. Spilker, P.K. Enge, and D.W. Parkinson, pp. 51-80, 1996.

3. “Technical Requirements Document CI-MGUE/GE-850, Military GPS User Equipment (MGUE) Ground-Embedded Form Factor Requirements,” Global Positioning System Directorate, Systems Engineering and Integration.

KEYWORDS: pseudolites, navigation warfare, PNT, External Augmentation Systems, BFEA, Blue Force Electronic Attack, MGUE, Military GPS User Equipment

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AF141-105 TITLE: Algorithms for IR data

KEY TECHNOLOGY AREA(S): Information Systems Technology

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OBJECTIVE: Develop data-processing methods and algorithms to exploit novel target signatures for insertion into ground- based processing software and real-time spacecraft data-processing firmware.

DESCRIPTION: Short-wave infrared (SWIR) surveillance scanning and staring systems have several missions, including missile warning, missile defense, battlespace awareness, technical intelligence, and environmental specification and forecasting. Of interest to these missions are data-processing methods and algorithms that exploit novel dim phenomena (targets, events, and environmental phenomena of military relevance). Each space system has its own features, which complicate the extraction of militarily-relevant information from large-format infrared images. In particular, the raw imagery contains artifacts, e.g., noise, internal reflections, etc., which must be characterized and corrected using data-processing methods and algorithms. It is anticipated that the most enabling concepts will involve innovative clutter suppression and mitigation techniques for SWIR see-to-ground bands (e.g., static sources, slow- or fast-moving objects), as well as track-before-detect approaches. The plan would be to insert the algorithms developed into existing baseline overhead persistent infrared (OPIR) software, at facilities such as the Aerospace Fusion Center, and to test the utility of the algorithms on flight-like hardware. This topic seeks innovation in the area of improved exploitation of SWIR image data acquired by space-based sensors viewing earth scenes.

Some typical artifacts and desired types of data (undesirable or mission) are listed below:
1. Reflections from ground (undesirable)
2. Reflections from the internal parts of the system (undesirable)
3. Noisy detectors (many types of noise) (undesirable)
4. High temperature detectors (undesirable)
5. Thermal distortion (undesirable)
6. Poor focus (undesirable)
7. Blinking detectors (undesirable)
8. Slow-moving objects – Tactical Parameter Estimates (TPE) such as trajectories and state vectors (mission)
9. Fast-moving objects – TPEs (mission)
10. Static sources (mission) a. Environmental b. Other
11. Transients (mission)
12. Geolocation – without stars (mission)
13. Closely-spaced objects (mission)
14. Cloud edges (mission and non-mission)
15. Technical parameter estimation (mission)

The small business doing this work must be certified for SECRET work. This project is restricted to no foreign release.

PHASE I: Develop real-time algorithms and evaluate them against supplied data to establish feasibility and payoff. Identify requirements for, and limits of, sensor technology on expected detection performance: framerate, wavebands, pointing stability, charge capacity, etc.

PHASE II: Code algorithms and test them against supplied data. Identify and test variations for framerate, wavebands, pointing stability changes as given in provided datasets. Propose CONOPs variations to improve performance.

PHASE III DUAL USE APPLICATIONS: Military: Space-based surveillance programs by DoD programs of record and new approaches for OPIR replenishment and modernization. Commercial: These IR specific algorithms are relevant to space-based weather information services, and may even enable new environmental monitoring capabilities.

REFERENCES:
1. A library of unclassified simulated data will be available for algorithm testing in Phase I.

2. A classified library of data will be available for algorithm testing against truth in Phase II.

3. H.l. Van Trees, "Detection, Estimation and Modulation Theory, Part I," Wiley-Interscience, 2001.

4. Levy, B.C., "Principles of Signal Detection and Parameter Estimation," Springer, New York, NY.

5. Sah, S. et al, "GPU accelerated real time rotation, scale and translation invariant image registration method," in proceeding of: International Conference on Image Analysis and Recognition, Volume: Image Analysis and Recognition Lecture Notes in Computer Science Volume 7324, 2012, pp 224-233. DOI:10.1007/978-3-642-31295-3_27.

6. Miaoqing Huang; Kilic, Ozlem, "Reaping the Processing Potential of FPGA on Double-Precision Floating-Point Operations: An Eigenvalue Solver Case Study," Field-Programmable Custom Computing Machines (FCCM), 2010 18th IEEE Annual International Symposium on , vol., no., pp.95,102, 2-4 May 2010. doi: 10.1109/FCCM.2010.23.

KEYWORDS: Infrared data, data processing, algorithm, electro-optical, space sensor

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AF141-106 TITLE: Innovative Technologies for Operationally Responsive Space

KEY TECHNOLOGY AREA(S): Space Platforms

OBJECTIVE: Develop technologies for spacecraft/space lift that provide game-changing "responsiveness" (ability to implement the same missions much faster and lower cost with adequate reliability and comparable capability thresholds/environmental constraints).

DESCRIPTION: The DoD is actively pursuing the capability to create and field a space mission within days (even hours) of a battlefield commander's notification. Achieving this capability for real-world missions is essential to the disruptive vision of the Operationally Responsive Space (ORS) Office. We believe implementing "big" missions to be done on "small" satellites is a game-changing approach for responsiveness, since smaller platforms (i.e., spacecraft) are easier to store, integrate, and launch. For this, technologies are the key. Can we find ways to more effectively miniaturize satellite sub-systems, components, and spacelift subsystems and components without compromising capability? Can we reduce the mass fraction of the spacecraft vehicle, so that more of it can be allocated to payloads? How can we pack more capable payloads into smaller containers, perhaps to be deployed once in orbit? Can we commoditize/modularize these approaches, so that they can easily be duplicated or commoditized to support multiple mission needs? Can we find similar improvements to space lift components to improve mass margin and launch capability?

We seek innovative concepts in miniaturized systems such as: compact, reconfigurable bus and payload components; modular/open/standardized payload configurations; high-performance, compact sensors; flexible operations schemes; space lift components and rapid integration; and improved on-ground and on-orbit calibration/check-out techniques. Can we break the perennial cycle of building custom hardware, software, and interfaces that leads to growing expense, schedule, and complexity? The ORS Office will also consider novel modification endeavors to existing commercial-off-the-shelf (COTS) components to meet the needs of this solicitation.

These technologies cover a broad range of the technical spectrum. The technical objective is to reduce the size of current satellites and space lift to one-half of their current mass and volume without loss of capability. More specifically, this effort involves development of innovative advances in structures, power systems, microelectronics, wiring systems, propulsion, attitude knowledge and control, space lift, and sensor systems that maintain capability while reducing volume and mass for an ORS-class mission. These systems should use standardized interfaces and integration schemes that make the launch of the satellite more responsive and operable for missions and launch campaigns associated with the ORS-class missions.

Contractors are strongly encouraged to work closely with the ORS Office and its contractors, if necessary, to ensure technical efforts are consistent with overall responsive satellite and space lift development goals. Proposed concepts should strive for designs that can eventually achieve a component fabrication and system integration time of a few days for the widest range of relevant satellite and space lift capability. In the near term, these techniques should cut integration time and component/mission costs in half.

PHASE I: Work out a convincing feasibility proof for the proposed concepts, ideally backed by simulation models, designs, fabrication, and other demonstrations. Establish the realism of these concepts and provide strong evidence that it will be possible to make meaningful progress in a Phase II program to achieve a "gettable" product, as opposed to a "fragment" needing other fragments to be useful.

PHASE II: Design, fabricate, and test a prototype-level concept that has functional specifications, interfaces, and protocols consistent with the ORS Office’s mission configurations. Ensure that the concept can work in the harsh environments of launch and space (e.g., shock, vibration, thermal cycling, radiation, spacecraft charging, etc.). Establish an integration strategy that will support the assembly and checkout of a small satellite within a few days based on the proposed concept.

PHASE III DUAL USE APPLICATIONS: Military: The ORS Office will have urgent use for this kind of technology. Commercial: The Commercial space industry will also have the ability to exploit such compact, capable systems for rapid deployment of communications and other commercial space missions.

REFERENCES:
1. Rapid Spacecraft Development: Results and Lessons Learned by William A. Watson, Rapid Spacecraft Development Office, GSFC 2002 IEEE Aerospace Conference, Big Sky, Montana.

2. Taking Advantage of Excess Spacelift Capacity—A vision for the Future, S. Buckley, Annual AIAA/Utah State University Conference on Small Satellites,” Utah State University, Logan, Utah, 13 August 2008.

3. Microsats for On-orbit Support Missions, DoE Report, Dr. A. G. Ledebuhr, UCRL-JC-142900.

4. Astrobiology Small Payloads, NASA/ARC Workshop Report, B. Yost, NASA/CP—2007–214565.

KEYWORDS: satellite bus, modular satellite, standardized satellite interfaces, spacecraft, payload, satellite, responsive space, responsive bus, space lift

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AF141-107 TITLE: Improved AFSCN FCT Simulator

KEY TECHNOLOGY AREA(S): Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop a low-cost hardware/software satellite testing system which can provide the functionality of the TSTR electronics and the RBC TSTR core electronics. This system will be used to demonstrate satellite system compatibility with the AFSCN.

DESCRIPTION: The Transportable Space Test and Evaluation Resource (TSTR) system provides deployable support for factory and launch site satellite compatibility tests. The deployable TSTR system, operated by the Mobile Range Flight (MRF) at the Space and Missile Systems Center (SMC) Space Development and Test Directorate, is used to accomplish satellite Factory Compatibility Tests (FCTs) with the Air Force Satellite Control Network (AFSCN) prior to satellite launches. Deploying and operating the TSTR for testing satellites for AFSCN compatibility has become painfully unaffordable for many satellite programs. As budgets are reduced, satellite programs are seeking lower-cost testing alternatives.

Developing a lower-cost testing system that is standardized and functionally equivalent to the TSTR and Remote Tracking Station Block Change (RBC) TSTR would greatly benefit numerous satellite development programs. The new testing system will verify and validate proper communication between the ground system and the satellite system under test, while being largely automated and sufficiently user friendly as to not require highly-specialized MRF personnel for on-site oversight. This would provide a lower-cost AFSCN compatibility testing capability for many satellite programs, while freeing up overburdened MRF testing resources. SMC desires a deployable TSTR-equivalent system that reduces the total system lifecycle ownership, deployment, and operations cost by 50% or more over the current standard.

With this test system, satellite programs could perform AFSCN compatibility tests and troubleshooting without having the actual TSTR system and MRF personnel on site. TSTR systems could be first augmented with, and perhaps later replaced by, the new test system, reducing the unsustainable high costs associated with operating and maintaining them. This test system will benefit all those who utilize the AFSCN network for conducting space TT&C or mission data distribution.

PHASE I: Perform analysis of AFSCN compatibility testing requirements to determine the optimal low-cost hardware and software capabilities necessary to perform ground system functional testing that verifies compatibility between Satellite Operation Centers (SOCs) via a simulated AFSCN Automated Remote Tracking Station (ARTS) and a RBC node represented by the TSTR and RBC TSTR systems.

PHASE II: Design and develop a prototype system that has the necessary hardware components and AFSCN simulator software to perform the required testing activities. Conduct a demonstration using both the prototype simulator suite and TSTR systems to successfully execute factory satellite-to-AFSCN compatibility test functions.

PHASE III DUAL USE APPLICATIONS: This system will reduce satellite development risk by ensuring AFSCN compatibility during AI&T, reducing the number of issues discovered during pre-launch checkout. Developing a largely software-based TSTR simulator will provide a much lower cost and robust test capability.

REFERENCES:
1. AFSCN Support for Operational Responsive Space (ORS), http://www.responsivespace.com/Papers/RS6/SESSIONS/SESSION%20I/1006_HODGES/1006P.pdf.

KEYWORDS: AFSCN Compatibility, Verification Test, Factory Compatibility Test, FCT, TSTR

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AF141-108 TITLE: Forecasting of Solar Eruptions using Statistical Mechanics, Ensemble, and Bayesian Forecasting Methods

KEY TECHNOLOGY AREA(S): Battlespace Environments

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Modify, develop and apply automated, machine-based learning systems and algorithms to assimilate, classify and identify solar eruptive activity and use the derived meta-data signals to predict and forecast solar eruptions.

DESCRIPTION: Solar eruptions (solar flares and coronal mass ejections) cause disruptions to communication and navigation in DOD and civilian systems. This SBIR seek solutions to forecasting solar eruptions using data modeling, from the perspectives of statistical mechanics, complexity, ensemble forecasting and Bayesian forecasting methods. Current consistent solar activity forecasts are issued once a day (24-hours), and require "human-in- the-loop". This SBIR seeks efforts at automated data-driven (no human in the loop) forecasts of 6-24 hour advance, which will be an improvement over current forecasts. It will require probabilistic predictions of future solar activity levels, greater than 50% confidence levels.

Consistent and reliable solar imaging data is openly available from many sources. They include NASA's Solar Dynamics Observatory (SDO) and its Atmospheric Imaging Assembly (AIA; ~ 12 layers) and Heliospheric Magnetic Imager (HMI ~ 3 layers) instrument, and other observatories/instruments that produce continuous high cadence solar imaging data. Hence it is now feasible to research and develop data driven models for supporting near-real-time advanced forecasting of solar activity. Such models can include auto-regressive forecasting models, machine learning, statistical physics data models (such as fluctuation dissipation theorem), complexity analysis, Bayesian learning systems, support vector machines, neural networks, multivariate discriminant analysis and genetic algorithms. Such algorithms have been applied to the forecasting of terrestrial weather.

A key objective of this work will the development of a verifiable set of test algorithms on independent test and training data sets based on a variety of eruptive and non-eruptive active region measurements. It will require algorithms to (a) automatically (no human in the loop) ingest solar imaging and non-imaging data from open sources to characterize current state of solar activity from various solar regions; (b) demonstrating meta-data relevant to characteristics of eruptive solar activity prior to eruptions' (c) developing Bayesian, statistical and/or machine-learning models specifically ingesting the relevant meta-data developed in item b to show continuous eruptive probabilities for application into 6-hour, 12-hour and 24-hour predictions; and (d) demonstrate the use of the data in real-time probabilistic prediction by using training and test cases. The references below point to potential algorithms that have been attempted.

Adapting Bayseian and related statistical algorithms tested and used in domains such as terrestrial numerical weather forecasting, Internet data mining and prediction tools, decision theory, or other statistical applications should be considered.

AFRL/RV plays a key role in understanding and predicting solar drivers of space weather, whose signals show significant impact on DoD communications and navigation systems and on its space assets. Providing impending/imminent status and an advance warning of the solar electromagnetic, particle and mass radiation on near-Earth and terrestrial systems, by a rapid ingestion and analysis of solar data, is vital to this process.

PHASE I: Develop & apply machine based learning systems to data-mine and rapidly extract meta-data specifying eruptive signals to classify eruptive solar activity. Develop verifiable forecast algorithms (no human in loop), using multi-spectral and near-simultaneous imaging data from SDO and other observatories. Demonstrate applications of algorithm robustness using limited training and test data.

PHASE II: Refine concept from Phase I and demonstrate ensemble forecasting from a variety of data sources and applied on a few thousand independent training and test cases. Apply to probabilistic forecasting of near-real-time data, for short-term (minutes), mid-term (hours < day) to longer-term (days) forecasting. Show results. Demonstrate statistical validation of results.

PHASE III DUAL USE APPLICATIONS: Implementation of ensemble forecasting for real-time applications for the DoD and/or other U.S. entities and organizations, such as U.S. Air Force, NOAA and NASA. Commercial Application: Same application for commercial.

REFERENCES:
1. Barnes, G., K. D. Leka, E. A. Schumer, and D. J. Della-Rose (2007): Probabilistic forecasting of solar flares from vector magnetogram data. Space Weather, 5, S09002.

2. Bornmann, P. L., and D. Shaw (1994): Flare rates and the MacIntosh active-region classifications. Sol. Phys., 150, 127-146.

3. Falconer, David A., Moore, Ronald L., Barghouty, Abdulnasser F., and Khazanov, Igor (2012): Prior Flaring as a Complement to Free Magnetic Energy for Forecasting Solar Eruptions. The Astrophysical Journal, Volume 757, Issue 1, article id. 32 (2012).

4. Crown, M. Validation of the NOAA Space Weather Prediction Center's solar flare forecasting look-up table and forecaster-issued probabilities. Space Weather: The International Journal of Research and Applications, Volume 10, CiteID S06006. 2012.

5. Norquist, D. C. and Balasubramaniam, K. S. Diagnosis of Solar Flare Probability from Chromosphere Image Sequences. DTIC, http://www.dtic.mil/docs/citations/ADA554688.

KEYWORDS: solar flares, data mining, forecasting, Bayesian algorithms, fluctuations dissipation theorem, multivariate discriminant analysis, support vector machines, space weather

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AF141-109 TITLE: Adaptive antenna structures

KEY TECHNOLOGY AREA(S): Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop antenna structure(s) or related items, capable of reducing radio frequency interference (RFI) susceptibility in RF-congested environments by controlling radiated and received emissions.

DESCRIPTION: The Air Force Satellite Control Network (AFSCN) finds itself operating in regions of increasingly congested Radio Frequency Interference (RFI). The advent of private and commercial 4G use, ad hoc networks, and increasing usage of adjacent bandwidths by these wireless device networks introduces more traffic into the L/S-bands, and threatens AFSCN stability. The advent of mobile data-enabled devices and mobile market expansion realizes unprecedented growth. Current projections call for a 15 times mobile-traffic increase by 2017 ("Traffic and Market Report June 2012", Ericsson). These projections will necessitate the adaptation of current AFSCN ground sites to prevent threats of possible site closure, disruptions in AFSCN coverage and service.

Adaptive Aperture would enable variable beam width operations that can be dynamically optimized once signal reception has occurred, incorporating at least 10 db edge taper improvements over existing 13 meter antenna. Would mitigate RFI and close-in neighbor's RFI to conduct satellite vehicle (SV) uplink activities via suppression shaping technologies (e.g., active spectral tapering and materials and controls technologies). The proposed solution space should provide enhanced sidelobe suppression up to the order of 10 db for uplinks up to 10kW CW.

To minimize cost and impact to current AFSCN sites, proposals should be limited to technologies that can be adapted into current 13-meter antennae (including subreflector, surfaces, legs, etc.), or surrounding external structure(s), such as the radome. As the antenna dish itself, and its related focusing elements and the radome have direct pattern and spectral effects, solutions in the form of structural or materials solutions are notionally feasible and implementable. These could include frequency-selective surfaces (FSS) or novel metamaterial-type surfaces on controllable elements, e.g., radome, sub-reflector modifications are approaches to consider. Constraints such as keeping losses low in the transmission bands and reception bands (maintain baseline efficiencies) while effectively reducing managing side-lobes is to be considered across the SGLS (L-band) and USB (S-band) frequency bands.

As this call is not for procurement of new antenna assets per se, it does indicate and opens tradeoff with several technologies and techniques that can modify or add capability via hardware and software to existing AFSCN-fielded assets. Some techniques, such as antenna nulling, for instance, may indicate feedhorn modifications or replacements, or development of active surface focusing shaping in the receive hardware, or both via dichroic structures.

Introduction of these technologies have the ability to reduce search and acquisition time to resolve SV orbits during launch, and space vehicle early-orbit ops. This can minimize spatial interference with multiple close-in SV contacts that are also not spectrally diverse. Also provides assured access to SVs in congested environments where those SV spatial and frequency/spectral assignments and external incoming interferences, from both ground and space, compete or are hostile.

An optimal capability would dynamically reduce beam width upon satellite vehicle contact and also control and contain spectrum (sidelobe management, dynamic gain, nulling). Enhanced capability to suppress side-lobe and spillover to minimize possibility of external RFI, and also reduce overall RF footprint is desired. Proposal should not address new whole antenna structures, or discrete arraying techniques.

Proposed solutions should be applicable to in-place AFSCN ground-stations. Produce a plan for prototype, test, and construction of a full-scale, or scaled application, for the antenna and/or radome structure. Show the potential or relative cost-benefit analysis of each solution. Use of EM models such as HFSS, Ansoft, CST, or other horn modelers, feed/antenna structure simulators is encouraged.

As applicable, demonstrate control/tuning mechanisms and show that antenna performance is not reduced in terms of loss, gain, efficiency, and show what additional investigations are required for operational high power uplink environment, or due to any other constraints that are determined in the course of solution validation.

PHASE I: Investigate approaches for modifying existing AFSCN antenna structures to produce desired side-lobe suppression and main-signal edge taper and control. Develop the baseline unmodified antenna model and an upgraded model with simulated results (pattern, spectrum) demonstrating accomplished objectives over the uplink and downlink bandwidths of interest for SGLS and USB.

PHASE II: Produce a prototype device and demonstrate capability in a laboratory setting that can be validated with the Phase I models. The prototype must be able to demonstrate relevant performance that indicates sufficient side-lobe suppression and taper control, or other main-beam enhancements can be achieved in a full-scale brassboard development.

PHASE III DUAL USE APPLICATIONS: Military: AFSCN ground sites to enable operation or enhanced agility where RF congested. Commercial: Cellular phone and mobile device market for transmission schemes.

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2. D. Kozakoff, "Analysis of Radome-Enclosed Antennas, Second Edition," Artech House, Boston, 2010.

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KEYWORDS: antenna aperture control, beam-focusing, adaptive antenna, active taper control, frequency selective surfaces, dichroics, beam nulling, radome beam control

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AF141-110 TITLE: Compact precision Atomic clock

KEY TECHNOLOGY AREA(S): Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US

Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop and demonstrate a liter scale atomic clock with 1E-16 long term stability suitable for space applications.

DESCRIPTION: Compact precision atomic clocks (CPAC) and atomic frequency standards (AFS) with 1E-16 term stability are capable of providing the timekeeping needs of future civilian and military systems. A space qualified clock can significantly increase GPS position accuracy and/or resilience to all users when installed on the GPS constellation, can increase position accuracy on space users with a poor view of the GPS constellation (e.g., vehicles at GEO), and can increase security for communication satellites. CPAC will also be useful for future inertial navigation devices.

The increased accuracy provided by the CPAC will also provide new tools for doing space-based scientific research which is critical for developing the future applications of a modern military. Research into gravitation (possibly gravity mapping), general relativity, and the fine structure constant are some examples (see references).

A CPAC would have ground applications as well because it could replace the hydrogen MASER as a ground reference. GPS ground station master clocks are required to maintain the constellation. Military R&D facilities could use the CPAC to test future timing devices. Commercial frequency standard producers can use the CPAC to calibrate future commercial instruments. These clocks have also been demonstrated for use as gravity detectors.

Clocks at 1E-15 stability have been demonstrated at the liter size scale, but new clocks in the last 5 years have moved to 1E-17 and recently 1E-18 (see references). These new clocks have been demonstrated at tens of liter scales in a laboratory. This effort will be an important next step in realizing these next generation timing devices in the compact foot print needed for this extra laboratory use.

The reliance of the warfighter on precision GPS cannot be overstated. A clock with the performance headroom in CPAC could significantly ease manufacturing concerns for GPS. The performance headroom allows for the easing of manufacturing tolerances required to meet GPS requirements and fulfill Space Command's Core Function Master Plan Priority #3. Also, the reduction of error loosens the reliance on external aiding and synchronization, which increases the robustness of the overall GPS system.

This effort is meant to focus on miniaturizing state of the art ultra-precise atomic clocks, especially the physics package, with some compromise on ultimate frequency stability to create a low size, weight, power and cost, as well as increase the robustness such that space compatible version of CPAC could be made.

PHASE I: Research and design a compact precision atomic clock for space with 1E-16 long term stability while maintain a final form factor under 5.5 liter with a goal under 1 liter.

PHASE II: Develop a prototype of the Phase I design and demonstrate short term stability of 1E-14 per square root of sample time and 1E-16 frequency stability at one day time.

PHASE III DUAL USE APPLICATIONS: Military: Compact atomic clocks could be incorporated into future navigation satellites to enhance navigation accuracy. Commercial: A derivative of the compact atomic clock could be used by the commercial timing instrument producers.

REFERENCES:
1. J. D. Prestage et. al., Liter sized ion clock with 1E-15 stability, Frequency Control Symposium and Exposition, 2005. Proceedings of the 2005 IEEE International, 472 (2005).

2. A.D. Ludlow et. al., Sr Lattice Clock at 1E-16 fractional uncertainty by remote optical evaluation with a Ca Clock, Science, 319, 1805 (2008).

3. N. Hinkley et. al., An atomic Clock with 1E-18 instability. Science Xpress 1240420.

4. T. Rosenband et. al., Ratio of Al+ and Hg+ Single Ion optical clocks; metrology at the 17th decimal place. Science 319 1808 (2008).

KEYWORDS: frequency standard, atomic clock, ion clock, atom interferometry, frequency comb

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AF141-111 TITLE: GPS receiver cryptography key delivery leveraging NSA's Key Management Infrastructure (KMI)

KEY TECHNOLOGY AREA(S): Electronics and Electronic Warfare

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Research the impact that NSA's new Key Management Infrastructure (KMI) will have on military GPS user equipment, key management operations and techniques that provide seamless transfer of cryptography key material directly to military GPS receivers.

DESCRIPTION: Military GPS user equipment (UE) receivers are physically and manually loaded with National Security Agency (NSA) generated cryptographic key material on a periodic basis to facilitate receiver processing of the encrypted P(Y) code signal set. This cryptograpic key material is currently electronically distributed worldwide via the Electronic Key Management System (EKMS) system. EKMS is a NSA-led program which generates and distributes electronic key material for all U.S. government encryption systems whose keys are loaded using standard fill devices, and manages the distribution of most of the NSA-produced key material.

EKMS is gradually being completely replaced by a new system, NSA's Key Management Infrastructure (KMI). KMI will provide a means for the secure ordering, generation, production, distribution, management and auditing of nearly all cryptographic products, to include all GPS UE key material worldwide.

GPS UE has some very unique key management challenges due to widely diverse receiver designs and a high amount of friendly foreign military participation. Traditional NSA-sponsored key management capabilities often do not take into account the kind of wide releasability and international involvement that is needed to support the huge, many-nation, GPS UE community. NSA's new KMI program will be bringing online a wide array of new features, capabilities, and also issues for users of GPS key material over the next five years. Some of these new features have the potential to significantly ease the key management and distribution burden for both U.S. military and friendly foreign military GPS users, but will require operational concepts, communications security (COMSEC) policy changes, and potentially hardware/software augmentation to be developed in order to take full advantage of these advancements. The GPS military UE community is falling behind on preparing for and socializing this major key distribution change and is soliciting research to help identify shortfalls and unaddressed issues associated with this upcoming migration from EKMS to KMI over the next several years.

This SBIR will investigate KMI features and evaluate them against current and projected future GPS U.S. military and friendly international military UE concept of operations (CONOPS) to identify pitfalls in order to assure seamless GPS keying operations for the warfighter. It will develop various operational use scenarios to highlight the benefits of KMI specific to GPS receivers, and prepare presentations that can be socialized to the larger military GPS UE community. It will identify features that require integration with GPS receivers, and develop a set of requirements that could be added to future GPS UE receiver contracts to enable greater support of "direct to receiver" keying through KMI.

PHASE I: Investigate KMI features and evaluate them against current and projected future GPS UE keying CONOPS to identify how the community can best benefit from this migration and any associated pitfalls. Develop operational use scenarios to highlight the benefits of KMI as it relates to military GPS receivers. Develop operational concepts that leverage KMI to enable direct receiver keying.

PHASE II: Develop technical requirements and operational concepts that could be required of future modernized GPS UE in order to take full advantage of the capabilities of KMI. Identify special hardware and/or software modules necessary to leverage the full spectrum of KMI capabilities and generate technical descriptions and requirements for those modules. Develop technical documents detailing a method to deliver key material that could work with unmodified, modernized GPS user equipment devices.

PHASE III DUAL USE APPLICATIONS: Build and demonstrate at least one mechanism to upload key material directly from the KMI system into modernized GPS user equipment. One of the mechanisms demonstrated must be able to support all foreign partners authorized to use encrypted military GPS receivers.

REFERENCES:
1. “DOT&E FY2012 Annual report: Key Management Infrastructure Increment 2,” http://www.dote.osd.mil/pub/reports/FY2012/pdf/dod/2012kmi.pdf.

2. “Operational Security Doctrine for the NAVSTAR Global Positioning System (GPS) Precise Positioning Service (PPS) User Segment Equipment," National Security Telecommunications and Information Systems Security Instruction (NSTISSI) No. 3006, August 2001.

3. "Key Delivery across the Last Mile,” CPT McNeace, CPT Thomas, CPT Pittman, CPT Berthelotte, Telecommunications System Engineering Capstone Project, University of Colorado. 2008.

KEYWORDS: GPS, key management, KMI, KMI Aware, Key fill, P(Y), EKMS

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AF141-113 TITLE: Selective Availability Anti-Spoofing Module (SAASM) Compliant GPS Receiver for GEO

KEY TECHNOLOGY AREA(S): Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop a rapidly converging, Selective Availability Anti-Spoofing Module (SAASM)-compliant GPS receiver for use at GEO.

DESCRIPTION: The current SAASM-compliant receiver compatible with GEO does not allow for sidelobe tracking, leading to long outages. Though currently-available compliant receivers exist, they do not meet current size, weight and power (SWAP) constraints. Because DoD has mandated all newly fielded DoD GPS systems use SAASM- compliant precise pointing system devices, there is an urgent need for a SAASM-compliant GPS receiver that is also low SWAP (<55cm3, =2.5lb, 20-34VDC, 7W max, including clock) for use at GEO with an accuracy of =50m. The receiver should be capable of converging to a solution within approximately 4 hours after a propulsive satellite orbit adjustment.

PHASE I: Design a SAASM-compliant GPS receiver for use at GEO with the above characteristics. Completion of Phase I is a CDR to the government. Presentation charts are the deliverable.

PHASE II: Develop an engineering model that demonstrates performance based on the government-approved Phase I design. Model can be laid out in a larger volume (bread-board type), but the model must illustrate that the components would fit within a 55cm3 package.

PHASE III DUAL USE APPLICATIONS: Dual-Use Applications: SAASM-compliant GPS receivers would benefit both military and civil GEO satellites, especially communications satellite programs that plan to have more than one satellite per GEO assigned slot.

REFERENCES:
1. Defense Science Board Task Force on: The Future of the Global Positioning Systems, Oct 2005, 109p.

2. Geosynchronous Satellite Use of GPS, J.L. Ruiz and C.H. Frey, ION GNSS 18th International Technical Meeting of the Satellite Division, 13-16 September 2005, Long Beach, CA, 6p.

3. SGR-GEO – Space GPS Receiver – Surrey Satellite Technology US. http://www.sst-us.com/shop/satellite-subsystems/gps/sgr-geo---space-gps-receiver-navigation-and-timing.

KEYWORDS: GPS, SAASM, space platforms, anti-spoofing

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AF141-121 TITLE: Satellite Threat Indications and Notification (TIN) in support of Space Situational Assessment

KEY TECHNOLOGY AREA(S): Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop algorithms to determine and assess space system threats and anomalies. The ability to differentiate anomalous conditions and to correctly assess man made threats and/or abnormal environment impacts is critical for future space systems.

DESCRIPTION: A critical need exists to be able to detect and discriminate between environmental conditions, man-made threats, and internal spacecraft anomalous conditions. In addition, a need exists to determine the mission impacts of these scenarios and recommend and/or execute courses of action in order to mitigate these conditions. To rapidly assess a threat to our space systems, algorithms are needed to process a wide variety of information sources including catalog, telemetry, and space environment data. Algorithms are needed that are capable of turning raw data into usable information. These individual data sources then need to be correlated to provide overall situational assessment which in turn then needs to be acted upon. This topic should take advantage of, and build on, years of research in level 0, 1, and 2 data fusion. For the purposes of this topic, level 0 fusion is defined as detection on an event within a single information source, level 1 is defined as the tracking of that event, and level 2 is defined as the correlation of events across multiple information sources in order to provide a more complete situational assessment. Accurate and reliable level 2 fusion systems in the DoD are rare, but strategically important. As a result, it is important to leverage previous work on real data to develop and extensively test level 2 data fusion capabilities for both space operations and counterspace applications. A key to the ability to correlate data is the need for an infrastructure that enables real-time communication between software entities. One such technology that provides that foundation is the Service Oriented Architecture (SOA). Within the Space Sector of the Air Force, an infrastructure that provides this capability is the Joint Space Operations Center (JSpOC) Mission Systems (JMS) SOA. Proposers should consider how their proposed solution would operate with the JMS architecture and proposals that include integration and demonstration within JMS will be viewed favorably. In support of JMS, the Space Vehicles Directorate of AFRL has developed a JMS testbed called the Advanced Research Collaborative and Development Environment (ARCADE). Depending on the proposed approach, the ARCADE testbed could be made available to proposers as a demonstration platform.

PHASE I: The focus of Phase I is to develop and demonstrate a proof-of-concept TIN prototype system that processes information sources such as those described above and provides appropriate responses. Performance assessment will include the accuracy, timeliness and mission impact.

PHASE II: Phase II will build on the Phase I prototype to include a wider variety of historical and real-time data sets. Emphasis will be placed on the ability to accurately characterize a situation. An emphasis will be placed on demonstration within the JMS ARCADE testbed.

PHASE III DUAL USE APPLICATIONS: The underlying technology to be developed focuses on applying intelligent systems technologies to the problem of detecting anomalous situations for satellites. Data fusion and validation tools have applicability to numerous areas beyond the space domain including the air and sea domains.

REFERENCES:
1. S Alfano, Satellite orbital Conjunction Reports Assessing Threatening Encounters in Space, 15th AIAA Space Flight Dynamics Conference, http://www.centerforspace.com/downloads/files/pubs/AAS-05-124.pdf.

2. Bowman, C. L., “The Dual Node Network (DNN) Data Fusion & Resource Management (DF&RM) Architecture,” AIAA Intelligent Systems Conference, Chicago, September 20-22, 2004.

KEYWORDS: Satellite Threat Indication, space situational assessment, information fusion, satellite threat detection

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AF141-122 TITLE: GPS PNT Flexible Satellite

KEY TECHNOLOGY AREA(S): Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Investigate designs and possible options for a PNT Flexible satellite for GPS to enhance position, navigation, and timing (PNT) capabilities, at a low cost.

DESCRIPTION: GPS augmentation systems enhance GPS constellation capabilities by providing additional PNT Flexible capabilities not inherent to GPS. It is desirable to use augmentation systems to maintain a more robust GPS service, particularly in areas where service interruptions are problematic, or better accuracy is needed.

While the GPS constellation provides good coverage worldwide, it is necessary to maintain the capability to provide that coverage during mission critical times. This leads to the need to explore the feasibility of developing an augmentation satellite at a significantly lower cost than GPS satellites that is able to broadcast a signal set that can enhance PNT capabilities and provide continuous GNSS coverage to the war fighter.

In order to address this problem, possible avenues could involve the exploration of using small satellites with limited payloads to reduce cost and meet mission essential needs. While the satellites may not be able to broadcast all signals simultaneously, it is more important to provide support to those GPS signals that are weak in a given location for any number of reasons. In other words, the augmentation satellite will help overcome GPS coverage issues due to terrain, spoofing, jamming, interference, etc., by broadcasting signals at a higher power than the constellation is able to provide to a specific geographic area.

At a minimum, the satellite should be able to transmit M-Code without boost in the L1 frequency band. Ideally, the satellite will be capable of transmitting P(Y), C/A, and M-Code with or without boost in the L1 frequency band. It is not required to transmit all signals simultaneously, that is, the satellite can utilize adaptive partial or whole signal set availability. For example, transmitting only P(Y) and C/A codes at L1 may be necessary for one location, but transmitting only M-Code at L1 may be needed for another location. All transmissions should be at power levels consistent with GPS core performance standards or better.

Proposals should clearly indicate how the result of the effort would be shown to improve the GPS system's capabilities through a test and validation plan. Testing and validation of risk reduction components of the overall effort in Phase I is encouraged. Phase II efforts should include ensuring compatibility with component interface descriptions supporting overall payload and space vehicle reference designs as part of their commercialization effort. Interface descriptions will be supplied to Phase I awardees invited to propose for Phase II.

Offerors are encouraged to work with PNT system prime contractors to help ensure applicability of their efforts and begin work towards technology transition.

Offerors should clearly indicate in their proposals what government furnished property or information are required for effort success. Requests for other-DoD contractor intellectual property will be rejected.

PHASE I: Efforts should concentrate on the development of the fundamental concepts for augmented GPS system accuracy, availability, operational continuity, or system integrity and plan to further develop this technology in Phase II.

PHASE II: The Phase II SBIR effort should utilize the innovation developed in Phase I and develop a simulation or architecture model to demonstrate the innovation. This should demonstrate the potential of the augmentation satellite to meet emerging operational needs. Demonstration of the augmentation of GPS system accuracy, availability, operational continuity, or system integrity must be validated.

PHASE III DUAL USE APPLICATIONS: Military application: GPS space and ground control segment. Commercial application: Wide Area Augmentation System (WAAS). Commercialization of the proposed innovation through a Phase III should motivate partnerships with other GPS system contractors.

REFERENCES:
1. Langley, R., Digging into GPS Integrity, GPS World, November 2011.

2. Betz, J., Something Old, Something New: Signal Structures for Satellite-Based Navigation: Past, Present, and Future, Inside GNSS, July-August 2013.

3. Divis, D., Air Force Proposes Dramatic Redesign for GPS Constellation, Inside GNSS, May-June 2013.

4. Anghileri, M. et al, Assessing GNS Data Message Performance, Inside GNSS, March-April 2013.

5. Kharisov, V. and Povalyaev, A., Optimal Aligning of the Sums of GNSS Navigation Signals, Inside GNSS, January-February 2012.

KEYWORDS: position, navigation, timing

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AF141-123 TITLE: Advanced Algorithms for Non-Resolved Space Based Space Sensing

KEY TECHNOLOGY AREA(S): Space Platforms

OBJECTIVE: Develop advanced algorithms that deliver significant improvements in characterization of deep space objects and Threat Indication and Notification (TIN) using unresolved photometric signature data.

DESCRIPTION: Space-based space surveillance systems require advanced object characterization algorithms for custody of deep-space objects and TIN. The Space Based Space Surveillance System (SBSS) and Space Surveillance Telescope (SST) are examples of such optical sensors that require advanced algorithms in order to perform their mission.

There is a need for development of advanced algorithms that exploit photometric data from sensors as the data becomes available using limited processing resources. State-of-the-art in satellite characterization is described in the references. For this solicitation, the focus of algorithm developments shall be to exploit passively-sensed photometric signatures, where the term signature is used to describe brightness changes with respect to observed solar phase angles or time. These signatures shall be used as the primary source of information that permits characterization of a Resident Space Object (RSO) or identification and notification of a threat. The Air Force's Advanced Research Computing and Development Environment (ARCADE) is where algorithms for threat identification and notification can be fielded to test and mature technology, prior to insertion in the Joint Space Operations Center (JSPOC) Mission System (JMS).

Additional concepts to consider in the algorithm development include calibration-error rejection and RSO stability. It is not a requirement that algorithms developed under this SBIR address all mentioned concepts.

PHASE I: Demonstrate feasibility of an innovative algorithmic approach for providing significant capability improvements in characterization of RSO signatures and TIN. Determine requirements for implementation in ARCADE.

PHASE II: Develop prototype algorithms in ARCADE to demonstrate potential ability to meet operational specifications, rapid characterization, TIN requirements, and the computing limitations of JMS. Validate with simulated and real-world data that demonstrates the potential for the developed algorithms to characterize objects and identify threats. Identify transition opportunities from ARCADE to JMS.

PHASE III DUAL USE APPLICATIONS: Military Application: This technology is envisioned for processing in the Joint Space Operations Center or data from SBSS, SST, and other space surveillance systems. Commercial Application: Monitoring commercial satellites.

REFERENCES:

1. http://www.boeing.com/defense-space/space/satellite/sbss.html.

2. Shelton, W., "Space Superiority," American Institute of Aeronautics and Astronautics International Air and Space Symposium and Exposition, AIAA 2003-2602, July 14-17, 2003.

3. A. Chaudhary, C. Birkemeier, S. Gregory, T. Payne, J. Brown, “Unmixing the Materials and Mechanics Contributions in Non-resolved Object Signatures,” AMOS Tech 2008.

4. K DeMars, M Jah, D Giza, and Tom Kelecy, “Orbit Determination Performance Improvements for High Area-To-Mass Ratio Space Object Tracking Using an Adaptive Gaussian Mixtures Estimation Algorithm,” International Symposium on Space Flight Dynamics, 2009.

5. T. Blake, Space Domain Awareness, http://www.amostech.com/TechnicalPapers/2011/SSA/BLAKE.pdf,

KEYWORDS: resident space object characterization, threat notification and warning, Space Based Surveillance System, Space Surveillance Telescope, Joint Space Operations Center Mission System

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AF141-124 TITLE: Space-based RF Emitter Detection and Localization Using Field Programmable Gate Arrays

KEY TECHNOLOGY AREA(S): Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: In support of protected, tactical communications, autonomy S&T solutions for compact low-cost RF space sensors that will timely respond to contested RF environments, including radar interferences, personal 3G/4G telecommunications, etc.

DESCRIPTION: Satellites are more vulnerable today to radio frequency (RF) jammers and high power in space-band transmitters due to availability of satellite operation information and low-cost RF equipment. In particular, satellite communications are facing increasingly more diverse physical, cyber, and natural threats from terrestrial stationary and/or mobile RF jammers that transmit RF jamming signals in the X/Ku/K/Ka/Q-band satellite communications. Thus, RF emitter detection and mitigation is essential for reliable satellite operations via communications, positioning, navigation and timing. As an effective proof-of-concept for space-based RF jamming detection and mitigation, this topic seeks to bring system concepts and software-hardware paradigms enabled by reconfigurable field-programmable gate arrays (FPGA) of smart antennas, RF emitter detection and localization computation which are communicating with orbital propagation simulations of a constellation of cubesat sensors running in NASA General Mission Analysis Tools (NASA GMAT) environments on a personal computer through User Data Protocol (UDP)/Internet Protocol (IP).

Responding to this opportunity and its technical challenges, low-cost solutions proposed should leverage from theoretical and practical fronts of geolocation; software defined radios for reconfigurable sampling rates, bandpass filtering, and intermediate frequency selections as required by X/Ku/K/Ka/Q-bands, and flexible FPGA for implementation of custom circuits of matrix-vector multiplications and parallelized algorithms. Innovative system concepts and enabling technology capabilities which are supported by advanced theoretical constructs and practical design principles shall include, but are not limited to: (i) modeling, simulation and analysis tools with life-cycle cost considerations for Low-Earth-Orbit (LEO)/Highly-Elliptical-Orbit (HEO)/GEO constellations of 5kg, 10cm x 10cm x 30cm cubesats together with multiple variables and parameters on operational areas of responsibility, revisit rates, RF sensing swaths, a host carrier with deployment mechanisms required to enter and exit waiting orbits for cubesat node separations, etc.; (ii) conceptual designs for smart wideband antenna and onboard sweeping frequency receivers to minimize FPGA resource and power requirements; (iii) low complex methods to extract X/Ku/K/Ka/Q-band spectrum characteristics, in addition of trade studies among Direction-of-Arrival (DOA), Time-Difference-of-Arrival (TDOA), and Frequency-Difference-of-Arrival (FDOA) assisted by earth surface information maps, if appropriate; (iv) operational issues of time and frequency synchronization of space-based transceivers; and (v) dynamic cubesat sensor management for effective RF sensing distribution and localization accuracy. Potential deliverables together with figures of merits as mentioned in (i) through (v) should include a software defined library of smart antenna emulation, smart antenna calibration, RF emitter alignment based on time markings and spectrum signatures as well as closed-loop performance evaluations of RF emitter detection and localization on custom FPGA hardware components and hybrid software-hardware approach.

PHASE I: Conceptualize mission designs and deployment operations of a constellation of 5kg, 10cm x 10cm x 30cm cubesats for RF emitter detection and localization as required in (i) & (ii). Parallelize the algorithms of 3D terrain-aided RF emitter localization for Xilinx FPGA Virtex 6 implementation. Demo dynamic cubesat sensor management in NASA GMAT. Assess onboard processing, size, mass, watt per pound.

PHASE II: Optimize Phase I results toward the technical challenges (iii)-(v). Characterize RF links & signal detection against signal to noise ratios, free space RF propagation models. Assess signal processing and communication delays due to sample collections, spectrum calculations and RF localization. Compensate receiver gains and phase delay differences. Demo FPGA-in-the-loop performance and NASA GMAT-based cubesat sensor allocation over RF radiations. Assess resiliency with a loss of cubesat sensors.

PHASE III DUAL USE APPLICATIONS: The technologies anticipated here are applicable to military, civil and commercial satellite communications, such as RF tomography, early RF threat warning and indications. Autonomy degrees of the technologies provide flexible negation capabilities for secure and resilient space communications.

REFERENCES:
1. Z. Wang, G. Chen, D. Shen, E. Blasch and K.D. Pham, “A Low Cost Near Real Time Two-UAS based Emitters Monitoring UWB Passive Radar System,” Proceedings of IEEE Radar Conference, Ottawa, Ontario, Canada, 2013.

2. Wang, Z., Pham, K.D., Blasch, E.P., and Chen, G., “Ground Jammer Localization with Two Satellites Based on The Fusion of Multiple Parameters,” SPIE Defense and Security 2011: Sensors and Systems for Space Applications IV, Proceedings of SPIE, Vol. 8044, Orlando, FL, 2011.

3. Wang, Z., Chen, G., Blasch, E., Pham, K.D., and Lynch, R., “Jamming Emitter Localization with Multiple UAVs Equipped with Smart Antennas,” SPIE Defense and Security 2010: Automatic Target Recognition XX; Acquisition, Tracking, Pointing, and Laser Systems Technologies XXIV; and Optical Pattern Recognition XXI, Proceedings of SPIE, Vol. 7696, Orlando, FL, 2010.

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5. Okello, N.and Musicki, D., “Emitter Geolocation with Two UAVs,” In Information, Decision and Control, IDC '07, pp. 254 – 259, 2007.

KEYWORDS: Smart antenna arrays, RF sensing swaths, wideband scanning receiver, antenna mutual coupling, phase delay difference, spectrum extraction, dynamic sensor management, FPGA, free space RF propagation, highly elliptical orbits, X/Ku/K/Ka/Q-bands, antenna calibration, RF detection and localization, earth surface information maps, cubesat constellation, deployment mechanisms, mission designs, host carrier operations, waiting orbits, life-cycle cost, system resiliency

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AF141-125 TITLE: GaN Technology for GPS L-band Space Power Amplification

KEY TECHNOLOGY AREA(S): Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop a high-performance Gallium Nitride-based (GaN) L-band Field Effect Transistor (FET) or a GaN-based Solid State Power Amplifier (SSPA) for GPS applications to reduce the cost of the GPS system through higher efficiency amplifiers.

DESCRIPTION: Improvements in efficiency resulting in lower power consumption and cost savings are required for future GPS L-band amplifiers. This solicitation is broad-based covering component design, and design architectures. Specifically sought are new and innovative approaches and technologies that will increase performance of space-based, high power L-band amplifiers. Radiation hardness and the ability for the technology to be qualified for space applications are crucial for successful proposals.

Any proposal submitted must first focus on high-efficiency GaN HEMT design, then a GaN HEMT-based amplifier design and development based on the optimized GaN HEMT. An offeror may submit multiple proposals with unique approaches in either area, but must lead to a high efficiency GaN HEMT-based SSPA.

A high efficiency GaN HEMT is needed for a solid-state L- band amplifier for GPS applications. GaN HEMTs have matured for ground applications, and have shown desirable characteristics for use in space applications; however, limited continuous wave operation, space experience or test data is available for them. Efforts for this topic should focus on GaN HEMT radiation tolerance, efficiency and bandwidth for use in L-band space amplifiers. This can be accomplished with development of innovative GaN HEMT designs focused on optimization for efficiency, radiation tolerance and bandwidth for L-band, space-based, GPS applications.

It is desired that a GaN HEMT SSPA design have greater than 60% efficiency as a goal, and desired power output is 400W. The SSPA needs to be compatible with the performance requirements of GPS L1 signals (see Reference 5 for technical specifications). Design efforts should focus on a high performance, high power amplifier optimized for power and efficiency. Efficiency for this amplifier should be specified in terms of Power Added Efficiency (PAE).

Proposals should clearly indicate how the result of the effort would be shown to improve the GPS system's capabilities through a test and validation plan. Testing and validation of risk reduction components of the overall effort in Phase I is encouraged.

Offerers are encouraged to work with PNT system prime contractors to help ensure applicability of their efforts and begin work towards technology transition.

Offerers should clearly indicate in their proposals what government furnished property or information are required for effort success. Requests for other-DoD contractor intellectual property will be rejected.

PHASE I: Design GaN FETs optimized for high power/efficiency and use in space-based L-band power amplifiers for GPS. Design should be radiation hardened, and simulated to show desired operation and performance characteristics. Design and simulate the SSPA the GaN FETs will be used in and, if possible, produce a working breadboard.

PHASE II: The selected company will team with a major contractor to produce working prototype GaN FETs for component evaluation and SSPA brassboard for amplifier evaluation, both including radiation tests. Phase II efforts should include ensuring compatibility w/Component Interface Descriptions (CID) supporting overall payload &space vehicle reference designs as part of their commercialization effort. CID will be supplied to Phase I awardees invited to propose for Phase II.

PHASE III DUAL USE APPLICATIONS: The selected company will produce GaN FET SSPA space-qualifiable prototype, complete radiation qualification testing data, for potential inclusion in GPS payload test flight.

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KEYWORDS: Gallium Arsenide, GaAs, Gallium Nitride, GaN, L-Band, Power Amplifier, Solid State, CID, Component Interface Descriptions

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AF141-126 TITLE: Optical System for Precision Atomic Clocks and Stable Oscillators

KEY TECHNOLOGY AREA(S): Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop and demonstrate a liter scale optical system to produce stable microwaves at 1E-14 per square root time and support an atomic clock with 1E-16 long term frequency stability suitable for space applications.

DESCRIPTION: Compact precision atomic clocks (CPAC) with 1E-16 long term stability are capable of providing the timekeeping needs of future civilian and military systems. A space-qualified clock can significantly increase GPS position accuracy and/or resilience to all users when installed on the GPS constellation, can increase position accuracy on space users with a poor view of the GPS constellation (e.g., vehicles at GEO), and can increase security for communication satellites.

The reliance of the warfighter on precision GPS cannot be overstated. A clock with the performance headroom in CPAC could significantly ease manufacturing concerns for GPS. The performance headroom allows for the easing of manufacturing tolerances required to meet GPS requirements and fulfill Space Command's Core Function Master Plan Priority #3. Also, the reduction of error loosens the reliance on external aiding and synchronization, which increases the robustness of the overall GPS system.

The most stable atomic clocks use optical transitions in atoms (see references). These systems require robust frequency combs and narrow line width lasers to take advantage of most promising atomic systems. This effort will focus on integrating frequency combs with narrow line with lasers, increasing their robustness, and decreasing their size weight and power requirements. The goals are to create an integrated frequency comb with narrow line width laser that is suitable for working with a CPAC with frequency stability of 1E-14 per square root of sample time and 1E-16 stability at one day. To that end, the system should be on the scale of liters, should output a stable and accessible microwave frequency between 1 MHz and 1 GHz, and should be capable of frequency locking to an atomic system at the CW laser wavelength used and be robust to temperature and mechanical instability at the same time. The system should conceivably be made radiation tolerant in a future effort.

The optical system described here can also be used without an atomic reference as replacement for solid state oscillators such as quartz or sapphire. The microwave output of this system will exceed, on short time scales, microwave references used in applications such as RADAR and communications and thus could improve capability in those areas.

There are many potential avenues to achieve these goals. There has been significant progress in developing narrow line width lasers with stabilized optical cavities and producing frequency combs with fiber laser based technologies and whispering gallery mode resonators as examples (see references). Any approach is acceptable, but should be justified as to how it meets the goals above.

PHASE I: Research and design a frequency comb integrated with a CW narrow line width laser system suitable for locking to an atomic optical transition of interest (examples like strontium, calcium, or ytterbium). The system should be designed to meet the goals in the description.

PHASE II: Develop a prototype of the Phase I design and demonstrate short-term stability of 1E-14 per square root of sampling time microwave output and the ability to frequency lock the optical system to an atomic system capable of supporting 1E-16 frequency stability at one day. Show that the prototype is robust to acoustic and temperature noise while frequency locked to an atomic system.

PHASE III DUAL USE APPLICATIONS: This optical system can be integrated into a compact precision atomic clock. These optical systems produce highly stable microwaves and could replace crystal oscillators in applications such as RADAR and communications.

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KEYWORDS: frequency standard, atomic clock, ion clock, frequency comb, optical clock, optical cavity

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AF141-129 TITLE: Mid-wave Infrared (MWIR) Illuminator for Ground and Small Unmanned Aircraft System (SUAS) Targeting

KEY TECHNOLOGY AREA(S): Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop high power, efficient MWIR illuminator to provide wide field-of-view illumination for hand-held, small weapon-mounted, remotely piloted aircraft, gunship, and helicopter applications.

DESCRIPTION: New technology is leading to MWIR sensors that are becoming pervasive on Air Force platforms. High-operating-temperature sensors are significantly lowering battery consumption for coolers and moving MWIR sensors into ground tactical and hand-held applications. The increased resolution and recognition range for smaller optics size, higher contrast scenes than long wave uncooled imagery, and other operational considerations, make MWIR an appealing imagery solution.

However, there is a need to enhance the power and cost efficiency of MWIR illuminator/pointers for surveillance and targeting applications to complement the current switch from LWIR to MWIR for platforms and, particularly, to provide a path for hand-held MWIR tactical systems.

To be effective at operating ranges from 100 meters to over 3 kilometer, solid state illuminators are needed. For SUAS and Remotely Piloted Aircraft (RPA), ranges of up to 10 kilometers are needed. Breakthroughs in MWIR Interband Cascade and Quantum Cascade lasers diodes led by DARPA and others have yielded near-room temperature laser diodes that promise near-term solid state, 10-12 watt illuminators for SUAS, hand held, and gunship operations.

Part of the challenge is to provide low-speckle output noise in the image frame without diffusers or other means that result in loss of a significant fraction of the output power. Two discrete zoom options are also needed to provide either a point source for identification to other sensors, or wide field of view for target illumination. Since many sensors are filtered differently over the 3-5 micrometer band, multi-color solutions are desirable with user control of output band to insure compatibility with ground targeting devices, SUAS, and targeting pod sensors.

Size, weight, power and turn-on time are critical. Batteries are a valuable commodity on SUAS platforms and man-carried or weapon-mounted applications. Hot standby in less than one minute is desirable with continuous run times of up to 30 minutes and intermittent 30 seconds on 1 minute off for up to 4 hours. The size goal for complete illuminator with optics and batteries is the size of current NIR and SWIR illuminators for weapon-mounted applications--3 inches long by 1 inch wide by 2 inches tall. Designed to be mounted on weapon rails or in a SUAS targeting gimbal.

Operational range equation must be considered in such a design and investigation. Limited small optical system size for both detector and illuminator drive the utility of the requirement. Cost is a key component, with a 1000-unit quantity goal of under $5,000 each. This drives innovation and efficiency to derive useable and affordable technology.

PHASE I: Investigate solid state uncooled or minimally cooled MWIR illuminator solutions for speckle-less pointing and targeting. Through critical experiment and analysis, show for limited optics size that sensor technology range equations show significant signal-to-noise improvement and target ID range improvement over passive only. Calculate system heat, power, and battery life of proposed approach.

PHASE II: Develop and demonstrate compact weapon and RPA/SUAS illuminator pointer with integral MWIR zoom optics and band selection. Show power, waste heat and cooler power management consistent with operational consideration and both ground and airborne uses in enclosed small gimbal packages. Show producibility approach to lower user cost in quantities to desired acquisition price point for long range ground-to-ground (100m to 3km) and air-to-ground (1km to 10km) applications.

PHASE III DUAL USE APPLICATIONS: Commercialize for law enforcement, marine navigation, commercial aviation enhanced vision, medical imaging venous and dermatological applications, and industrial semiconductor and manufacturing process control.

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KEYWORDS: MWIR, Illuminator, laser pointer, laser illuminator, weapon sight, SUAS, remote piloted aircraft, targeting gimbal, remotely piloted aircraft

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AF141-130 TITLE: Miniature line-of-sight optical stabilization for hand-held laser marker/designator

KEY TECHNOLOGY AREA(S): Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop miniature laser line-of-sight (LOS) optical stabilization device for hand-held laser marking/designation applications that incorporates “see-spot” and target tracking capability.

DESCRIPTION: As the size and weight of laser targeting markers and rangefinders have decreased, numerous hand-held (non-tripod) applications have been developed. Unfortunately, these small systems are unstable and require improved line-of-sight (LOS) stability to hold the laser spot on the target at long ranges and to minimize laser jitter over and under the target. Eventual goal is laser on-the-move.

Hand-held laser designators do not offer any laser beam stabilization and often lack any imaging or target tracking capabilities. Without stabilization, laser energy is smeared on the target. For example, a 300 microradian divergence laser beam at 1 km will be 30 cm in diameter. Any motion induced by the operator will cause the 30 cm spot to travel on the target. In a scenario where the spot never leaves the target, but is also not stationary, a laser spot tracker may not lock onto the target since the average energy is too low.

Another scenario is where the spot “spills-over” the target due to the large spot size relative to the target, and sometimes the lack of an integrated target tracker. In this case, beam energy is completely lost (or worse, placed on the wrong target!). Even with training, the operator can induce LOS disturbances on the order of several degrees during target designation, which can result in 30 feet of target designation error at a range of 2 to 3 km.

Thus there is a need for a compact laser marking/designation system capable of compensating for small disturbances induced by the operator. New technologies must be developed that can stabilize laser beams (and possibly imaging LOS) without the size and weight impacts of previous systems. Using modern image sensors, such as a short-wave IR (SWIR) or a 1064 nm sensitive EO camera, and a target tracker, the laser spot could be placed on a target and maintain pointing accuracy even with gross user motion. Since the SWIR or Low Light EO targeting camera system is capable of seeing the laser spot, the system could provide the user with a digital video feed along with the laser spot position in the scene.

Recent developments have been focused on small, hand-held target designators the size of a 1-liter water bottle that have both direct-view optics, electro-optical day/night sights, and laser pointer/illuminator/designator. Concepts that help stabilize these compact multifunction instruments are needed. This may include an all-aperture stabilization or laser beam stabilization with feedback, and electronic stabilization of the other sensors. In any case, the LOS needs to be indicated to the operator for the location of the IR non-visible beam direction and target location.

Peak powers from Q-switched lasers for military applications are exceedingly high. For short pulses of 1 to 20 nanoseconds, peak powers of over a megawatt are not unusual with average powers for some systems exceeding 10 watts. Approaches must be compatible the intense powers and damage thresholds represented in these types of laser systems.

PHASE I: Investigate innovations for stabilizing laser designator or rangefinder beams to less than 50 microradians RMS. Perform experiments showing the ability to reject low-frequency (0-10Hz) angular motions with displacements of plus or minus 2 degs-all axes. Develop algorithms/simulations predicting LOS jitter performance. Develop design concepts for miniaturization into a hand-held form factor.

PHASE II: Develop a hand-held sized prototype capable of integrating the see-spot imaging system, laser designator, laser beam steering system, and video display. This prototype will demonstrate the feasibility of the system recommended in Phase I.

PHASE III DUAL USE APPLICATIONS: Develop, integrate and transition for military applications in Air Force, Army, and Marine Corp laser targeting devices. Commercial applications in rangefinders and markers for surveying, long-range hunting sight applications, security, and industrial measurements.

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KEYWORDS: laser designator, laser marker, stabilization, line of sight, optical jitter suppression, laser rangefinder

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AF141-131 TITLE: Electromagnetic Radiation Effects on Weapons and Energetic Materials

KEY TECHNOLOGY AREA(S): Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors

are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Perform innovative research in electromagnetic radiation (EMR) effects on energetic materials (EMs). Develop electrical and physicochemical models of EMs to predict safety and energy output under various physical, chemical, and EMR conditions.

DESCRIPTION: Ubiquitous radio frequency (RF) and electromagnetic radiation (EMR) usage is an important characteristic of modern military. While EMR offers many benefits, there are disadvantages associated with the EMR-rich environment. One of the disadvantages of EMR is "Hazard of Electromagnetic Radiation to Ordnance" (HERO). HERO may cause inadvertent activation of a munition. A fundamental and scientific understanding is lacking as to why and how EMR impacts explosives at the molecular level and causes an inadvertent activation of the explosive. Besides the inadvertent initiation of an explosive material, EMR could alter an explosive's performance.

The fundamental mechanisms that take place when an explosive is exposed to EMR needs to be studied, modeled, and validated. This is basic research that brings multiple scientific fields together. The goal of this innovative research is twofold: to develop a physicochemical model, and an electrical model to predict energetic material performance both for safety as well as for energy throughput. The models developed should incorporate all physical, chemical, temporal, and EMR parameters. The purpose of such models is to help understand the safety features needed in the design of a munition and also to design new materials.

The question that needs addressed in this research through the validated models is: What characteristics of EMR and energetic material play a critical role for both safety as well as throughput?

PHASE I: Develop theory, and develop first principle physics based physicochemical and electrical models and algorithms for EMs and EMR interaction. Deliverables include a technical report documenting the theory of model development, proof that models and algorithms are relevant, feasible and valid for at least some classes of materials under key parametric conditions of EMR and materials.

PHASE II: Enhance and refine the models and algorithms developed in Phase I. Show by analysis and experiments that they are accurate and valid for multiple classes of materials under a number of various physical, chemical and EMR parametric conditions. Deliverables include detailed technical reports, algorithm and model specifics, rationale, and experimentally demonstrated validation evidence for multiple materials under scores of parametric conditions of EMR and material property variations.

PHASE III DUAL USE APPLICATIONS: Military applications are munitions safety, and munitions performance characterization. Commercial applications include explosives safety weapons for law enforcement; automobile airbag enhanced safety, reliability, and efficient airbags.

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KEYWORDS: energetic materials, explosives, electromagnetic radiation, physicochemical model, electrical equivalent circuits, modeling, power, energy, pulse width, continuous wave, CW, pulsed energy, figure of merit, algorithms, chemical composition.

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AF141-132 TITLE: Wide Field of View High Speed Strap Down Stellar Inertial Instrument

KEY TECHNOLOGY AREA(S): Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop a compact, low profile, wide field-of-view day/night stellar inertial technology for use in severe weapon environments (vibration, thermal, etc.).

DESCRIPTION: A solution is needed for weapon and long-range platform operations with minimal reliance on GPS, or preferably without any GPS. A precision navigation solution that operates with minimal reliance on GPS, or preferably without any GPS, is needed for airborne platforms as well as air launched weapons. One potential solution is a stellar inertial navigation sensor consisting of a star tracker coupled to an inertial measurement unit (IMU). However, currently available stellar inertial sensors operating without GPS augmentation are not capable of providing GPS-quality accuracies. One reason for this is the error in the estimate of the orientation of the horizon plane, and hence the local vertical vector. Each microradian error in the local vertical translates to about six meters of error for Earth coordinate (lat/long) estimates. Sensors that directly observe or measure the local vertical accurately on a moving vibrating airborne platform can greatly increase accuracy. Another problem with the present-day stellar inertial sensors is the narrow field of view of the star tracker. A wide field-of-view star tracker would reduce errors due to platform movements and vibrations.

Proposals should describe a breadboard-level inertial navigation system (INS) coupled to other sensors, such as star trackers, to provide a complete non-GPS navigation solution. Accuracy, size, weight and power (SWaP) estimates for near-term prototypes should be provided and fully justified.

The need is for a day/night wide field-of-view WFOV Strap Down Star Tracker for very high speed missile and long range weapon applications with secondary applications to remote piloted aircraft (RPA) and ground applications for North Finding. The location of a sensor for advanced high speed missiles and platforms is frequently non optimal and requires a small footprint. The sensor must be strap down without mechanical gimbal or mirrors and have a large FOV. Approaches to address severe vibration and heat must be self-normalizing without in situ calibration or more than 30 seconds of initialization. The technology should operate day or night with thin cloud obscuration from 1,000 feet to 100,000-foot and higher altitudes. The approach should not be dependent on collocation or hard mounting to the IMU. A thin package for body mounting is needed to lack of depth and volume in the most probable mounting location for best view of objects. Atmospheric effects of turbulence and refraction as a function of altitude and novel approaches to derive down vector without magnetic gradiometers must be addressed. To provide additional space object versus star discrimination with severe vibration, a high speed sensor is anticipated for operation to derive angle rates as well as absolute position independently.

Address dual use of the technology for AFSOC ground targeting sensors, RPA platforms, and fixed wing fighter and bomber aircraft.

It is envisioned a Phase II limited flight demonstration joint with the Air Force Test Pilot School, Naval Post Graduate School, or University or Prime Contractor is a key desirement to establish transition readiness.

PHASE I: Design a navigation sensor that can provide GPS comparable accuracy without any GPS. Simulate multiple flight trajectories and estimate accuracy using high fidelity models that take into consideration weather, clouds, and other environmental conditions, platform movement, rotation, and vibration. The design should be mature at the end of the Phase I effort with lab demo of critical elements.

PHASE II: Develop and integrate component technologies, interfaces, and software necessary to demonstrate a prototype of the navigation sensor in the laboratory and outdoors - preferably at low elevation and at high elevation. A flight test ready prototype at the end of the Phase II effort is highly desirable. Develop an ICD and transition plan and coordinate with Air Force platform programs and DoD Inertial Systems prime contractors for rapid technology insertion.

PHASE III DUAL USE APPLICATIONS: Develop and transition a deployable navigation sensor for use in government and defense industry applications.

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KEYWORDS: Star Tracker, navigation sensor, guidance, navigation, strap down, high speed sensor

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AF141-133 TITLE: High Performance Angular Rate Sensors for Compact Inertial Guidance without GPS

KEY TECHNOLOGY AREA(S): Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual

use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop advanced miniaturized angular rate sensors (Gyros) to address military weapons environment and need to improve inertial measurement unit accuracy to very low drift strategic grade in a tactical weapon sized inertial package.

DESCRIPTION: Very little investment in precision inertial measurement unit (IMU) technologies for tactical weapons has been made in recent years due to reliance on GPS and other radio navigation technologies. The goal of this research is to address gaps in very high performance angular rate sensors to improve tactical IMUs to strategic grade for long-range weapons guidance without GPS.

A good form factor to consider is the Honeywell HG1700 fiber laser gyro IMU. It provides reasonable performance under a wide range of operation when disciplined with periodic GPS inputs. The drift rates of the fiber laser and accelerometer errors cause navigation errors over longer flight times for long range weapon and RPA platforms. Sixty seconds of flight time without GPS results in meters of error. Several hours can result in kilometers of error. Improvements to existing angular rate sensors are needed to improve long term guidance without GPS update at an affordable cost.

A small IMU footprint is needed for weapons IMU (i.e., performance of a Honeywell HG9900 or Northrop Grumman LN250 in a Honeywell HG1700 form factor). The IMUs are typically mounted at the rear of a weapon and can experience severe vibration and heat. To minimize impact to existing weapon load out and form factor, the goal is to fit into existing IMU packages with a rate sensor goal footprint or 10 cubic inches or better for a Tri-Axial rate sensor package with integrated electronics. This area also includes the support electronics/electro-optics to transition into integrated radiation and severe environment package.

The eventual size goal is: Full IMU (3 Gyros + 3 Accelerometers + IMU sensor Processing & Data Interfaces) < 50 Cubic inches (with objective = 34 Cubic inches, which is the size of the HG 1700 JDAM IMU) (Note that HG9900 is about 103 Cubic inches). For position accuracy, the goal is less than 0.03 m (3D; 1-Sigma) in a 100 seconds of inertial only flight (assume initial alignment) reflecting current gravity weapon dynamics.

For consideration, assume improving current gyro bias to less than 0.0005 degree/hour will produce a position error of 0.015 m in 100 seconds. The accelerometer bias of 100 nano-G will likewise produce a position error about 0.005 m in 100 seconds. Therefore, the overall IMU position error should be in the 0.03 m range given a 100 seconds time of flight.

The major contributors to the final position error will be the mechanization errors such as algorithmic, misalignment, etc. Other errors for new sensors IMU will have apart from the most obvious ones, such as the misalignment and algorithmic, must be assessed and identified. The characterization phase of the IMU sensors should provide that info. The 0.03 m error due to gyro and accelerometer biases simply means that biases are no longer the limitations, and their contributions wash out when compared to other errors.

The goals for an advanced IMU sensor are: Near Term (3-5 Years) Gyro 0.003 Deg/Hr; size less than 100 cubic inches. For Mid- Term Goals (5-10 Years), assume an angular drift rate approaching 0.0003 Deg/Hr and size of less than 50 cubic inches. For long term applications (10 years out), an angular drift rate of 0.00003 Deg/Hr or less total volume of < 10 Cubic inches is the desired goal. A tactical IMU including gyros and accelerometers cost goal is unit production cost of under $15 K.

Tasks to get to a weapons grade IMU from sensors to be addressed include: characterization of errors to develop a full error budget for gyro and accelerometer triads; inertial navigation performance analysis including covariance and/or Monte-Carlo simulations In a weapon flight time (degraded GPS, fully denied-GPS); and laboratory/flight simulation qualification under weapon dynamics and environments.

PHASE I: Research novel wide operating temperature triaxial angular rate sensors (Gyros) that can augment current and future weapon IMUs for long range navigation without GPS. Demonstrate principals of physics with critical lab experiments and show by analysis and modeling the extrapolation based on packaging and manufacturing technology maturity and transition for a five-year insertion goal.

PHASE II: Develop, integrate, and test prototype IMU sensor components. Demonstrate through laboratory and simulated flight environment testing suitability for high sensitivity with low drift rates. Show through analysis, test and modeling that the proposed technology approach is compatible, supportable and improves current weapons IMU navigation systems performance. Develop hardware in the loop or flight test experiment modules for detailed characterization in simulated weapon trajectory environment.

PHASE III DUAL USE APPLICATIONS: Develop and transition technology to DoD weapon and platform applications, commercial vehicle and aircraft navigation, and underground transportation applications with degraded GPS signals.

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KEYWORDS: Inertial Measurement Unit, angular rate sensors, gyros, triaxial, Laser Gyro, Rate Gyro, drift, GPS Denied

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AF141-134 TITLE: Integrated Opto-Electronic Components for Multiaxis Inertial Measurement Units

KEY TECHNOLOGY AREA(S): Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop integrated opto-electronic technologies that can provide for miniaturization, integration, and weapons environment operation of atomic interferometric, superluminal, resonant photonics, magneto resonant gyros and accelerometers for weapons.

DESCRIPTION: The Air Force is developing advanced technologies leading to small compact weapon systems, which need micro-inertial measurement systems far beyond current state of the art.

These applications range from unmanned air systems (UAS), micro-air-vehicles (MAVS), miniature precision guided weapons, compact high performance missile and air launched interceptors, and advanced laser beam pointing/steering systems. A pervasive need is for robust small footprint inertial sensors that have robust environmental characteristics and extreme sensitivity. Continued navigation, sensor direction, and operation either in a GPS jammed environment, terrain masking scenarios, or other severe environments is a persistent Air Force need.

Recent DARPA, Air Force, and MDA, developments have demonstrated gyros, rate sensors, and other instruments based on optically pumped rubidium and cesium using single frequency semiconductor lasers precisely tuned to the atomic resonance transition. These experiments using “atom” optics have shown great potential but have a long path to small system insertion. Recent experiments with “Fast Light” have shown promising results to provide nearer term insertion with small footprint and an order of magnitude accuracy improvement.

Rubidium and cesium atomic sensor devices have shown promise for compact inertial microsystem applications, but are a long way from transition into practical, ruggedized 3-axis flight and ground system applications. Basic research experiments as derivatives of chip scale atomic clocks have shown that hybrid integrated optical-fast light devices could potentially have large expensive laser ring gyro performance in sizes as small as 1 cubic centimeter.

A key stumbling block is application of integrated optronics to miniaturize the racks of electronics used support these novel sensors into a compact weapon footprint IMU. This topic seeks to exploit integrated electro-optics to miniaturize and share common functions to achieve the IMU 10-cubic- inch size goals for precision weapons.

Recent breakthroughs in single frequency semiconductor laser diodes and bidirectional amplifiers have enabled a conceptual integration into a single laser driven multi-axis inertial sensors with sense nodes on sub-centimeter cubed scale. These lasers are marginally available today from an offshore supplier, but DoD users and other contacts report long delivery times, low reliability, and frequent failure to meet published specifications. Emerging domestic suppliers must be developed to ensure stable sources of supply of these precision lasers.

Miniaturized, frequency-agile, robust laser systems that can operate autonomously while locked to atomic transitions with prescribed offsets up to 10 GHz are also needed.

The SBIR topic solicits novel concepts and technologies in design, development, and demonstration of components, subsystems, and systems to support integrated optical atomic/quantum 3-axis IMUs for rotational and linear inertial sensing (Inertial Measurement Units), replacement of digital compasses, and target weapon fuzing.

Key components should provide for stable operation of the drive and probe lasers, feedback and control of frequency and stability, microwave modulation of frequency for offsets (e.g., Rb 85 and Rb 87 at 795 and 780 nanometers or Cesium D1 and D2 lines at 894 and 852 nanometers respectively).

The sensing system should be able to withstand missile and tactical fighter aircraft temperature, acceleration, and vibration environments and not be sensitive to electro-magnetic interference (EMI).

PHASE I: Investigate integrated opto-electronics for advanced angular rate and acceleration sensors. By simulation and/or critical component experiments, show feasibility of the proposed approach. Investigate lasers, modulators, detectors and electro-optic components for inertial sensors. Address stability, performance, and single frequency laser power technology. Address integration into weapon IMUs.

PHASE II: Design, develop, and characterize prototypes of the proposed technologies and demonstrate functionality. Demonstrate feasibility and engineering scale-up of technology; identify and address technological hurdles. Demonstrate applicability to selected military weapon systems and aircraft/spacecraft environments, including vacuum, cryogenic operation, and radiation exposure. Desired demonstration in laboratory inertial test environments simulating weapon, missile flight dynamic environments.

PHASE III DUAL USE APPLICATIONS: Develop and execute a plan to manufacture the micro-optical atomic inertial component, subsystem, or system developed in Phase II. Assist the Air Force in transitioning this technology to the appropriate prime contractor for the system development and demonstration phase.

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KEYWORDS: inertial navigation, microwave photonics, attitude, MEMS, fast-light enhanced laser gyro, integrated optics, grating outcoupled single frequency laser diode, integrated optics, attitude determination, Micro Air Vehicle, Integrated Targeting Device

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AF141-135 TITLE: High Performance Accelerometers for Precision Attack Weapons

KEY TECHNOLOGY AREA(S): Weapons

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OBJECTIVE: Develop high performance accelerometers in a tactical size and cost range to dramatically enhance tactical IMU’s to strategic grade for long range weapons guidance without GPS.

DESCRIPTION: This topic is to address investigations of novel approaches for compact strategic grade accelerometers suited for tactical munitions. The goal is to develop high performance, compact form factor, ruggedized accelerometer to improve tactical IMUs for long duration guidance without GPS. Current accelerometers limit IMU accuracy as much as deficiencies in gyro rate sensors. There have been several advanced MEMS-based resonant structure accelerometers investigated for space applications that are approaching 1 micro G or better sensitivities but the severe vibration and heat environment range for tactical application limits their suitability. The environment ranges from very cold at start up -40 degrees C to above 70 degrees C ambient with severe vibration and heat.

Very little investment in precision inertial measurement unit (IMU) technologies for tactical weapons has been made in recent years due to reliance on GPS and other radio navigation technologies. The goal of this research is to address gaps in high performance accelerometers improve tactical IMUs to strategic grade for long duration guidance without GPS.

A good form factor to consider is the Honeywell HG1700 fiber laser gyro IMU. It provides reasonable performance under a wide range of operations when disciplined with periodic GPS inputs. The drift rates of the fiber laser and accelerometer errors cause navigation errors over longer flight times for weapon and RPA platforms. Sixty seconds of flight time without GPS results in meters of error. Several hours can result in kilometers of error. Improvements to existing IMU acceleration sensors are needed to improve long term guidance without GPS update at an affordable cost.

A small IMU footprint is needed for weapon IMUs (i.e., the performance of a Honeywell HG9900 or Northrop Grumman LN250 in a Honeywell HG1700 form factor). The IMUs are typically mounted at the rear of a weapon and can experience severe vibration and heat. To minimize impact to existing weapon loadout and form factor, the goal is to fit into existing IMU packages with a sensor goal footprint of 1 cubic centimeter or better for a Tri-Axial accelerometer package with integrated electronics. This area also includes the support electronics/electro-optics to transition into integrated radiation and severe environment packages.

The eventual size goal is: Full IMU package (3 Gyros + 3 Accelerometers + IMU sensor Processing & Data Interfaces) in less than 50 Cubic inches (with objective of 34 Cubic Inches, which is the size of the HG 1700 IMU). The position accuracy goal is less than 0.03 m (3D 1-Sigma) in 100 seconds of inertial only flight (assume initial alignment) for current gravity drop weapons. (Note that HG9900 IMU is about 103 Cubic inches) For consideration, assuming that just improving current IMU gyro bias to less than 0.0005 deg/hr will produce a position error of 0.015 m in 100 sec. The other impact is improving accelerometer bias. An accelerometer bias of 100 nano-G will likewise produce a position error about 0.005 m in 100 sec. The overall IMU position error should be in the 0.03 m range given a 100 sec time of flight.

The major contributors to the final position error will be the mechanization errors such as algorithmic, misalignment, etc. Other errors for new sensors IMU will have apart from the most obvious ones such as the misalignment and algorithmic must be assessed and identified. The characterization phase of the IMU sensors should provide that info. The 0.03 m error due to gyro and accelerometer biases simply means that biases are no longer the limitations, and their contributions washes out when compared to other errors.

The goals for IMU acceleration sensor are: Near-term (3-5 Years), accelerometer sensitivity 25 Micro-G with IMU size less than 100 cubic inches. For mid-term goals (5-10 years), assume an acceleration sensitivity of 2.5 Micro-G and IMU size of less than 50 cubic inches. For long term applications (10 years out), acceleration sensitivity of less than 1 Micro-G with total volume smaller than 20 cubic inches is the desired goal. A tactical IMU cost goal, including angular rate and accelerometer sensors, is a unit production cost of under $15 K.

Tasks to get to a weapons grade IMU from sensors to be addressed include the following: characterization of errors to develop a full error budget for gyro and accelerometer triads; inertial navigation performance analysis including covariance and/or Monte-Carlo simulations in a weapon flight time (limited GPS); and laboratory/flight simulation qualification under weapon dynamics, and flight environments. It is desired that in phase II prototype modules be available for government HWIL and flight testing at the end of Phase II and in Phase III.

PHASE I: Research novel wide operating temperature compact triaxial acceleration sensors that can augment current and future weapon IMUs for long range navigation without GPS. Demonstrate principals of physics with critical lab experiments and show by analysis and modeling the extrapolation based on packaging and manufacturing technology maturity and transition for a five year insertion goal.

PHASE II: Develop and test prototype accelerometers with IMU components. Demonstrate, through laboratory and simulated flight environment testing, suitability for high sensitivity with low drift rates. Show through analysis, test, and modeling that the proposed technology approach is compatible, supportable and improves current weapons IMU navigation systems performance. Develop hardware in the loop or flight test experiment modules for detailed characterization in simulated weapon trajectory environment.

PHASE III DUAL USE APPLICATIONS: Develop and transition technology to DoD weapon and platform applications, commercial vehicle and aircraft navigation, and underground transportation applications with degraded GPS signals.

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KEYWORDS: Inertial Measurement Unit, Accelerometers, triaxial, drift, GPS Denied, fiber optic accelerometer, integrated optics, MEMS, atomic optics

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AF141-136 TITLE: Dual Mode Seeker/Sensor -LADAR/RF

KEY TECHNOLOGY AREA(S): Weapons

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of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Research and develop dual-mode LADAR/RF seeker with hand-off operation capable of detection and targeting in GPS-degraded and GPS-denied environment.

DESCRIPTION: As part of an analysis of operating in GPS-degraded and GPS-denied environments, the Air Force has identified potential shortcomings in the terminal seeker technology of its existing arsenal of air-to-ground and stand-off weapons. The expected long ingress ranges and the high likelihood of encountering electronic counter-measures (such as GPS jamming) make it necessary to pursue robust weapon seekers possessing the best characteristics of both LADAR/IR and RF systems. Existing seekers do not currently possess the ability to detect targets at the desired long ranges and are not dual-mode capable of terminal high-resolution imaging.

AFRL desires technology solutions for a dual-mode terminal seeker incorporating active RF target acquisition and LADAR imaging. The seeker technology should be engineered for SEAD/DEAD missions against fixed emplacements, possibly obscured by camouflage, concealment and deception (CC&D). Threshold detection of ground targets, using RF, should occur at ranges between 20 to 40km. In the terminal phase, the seeker should be capable of using multi-hit LADAR returns to perform target imaging and acquisition. Detection of targets with low reflectivity is desired, although this should be accomplished using minimal power.

Seeker should be expected to operate day/night and in weather conditions to include clouds, haze/smoke, and rain. This is consistent with other fielded weapon systems, which must be employable in all conditions where the expected strike platforms (5th/6th-generation aircraft) can operate.

Constraints on the design include overall size (5” - 7” diameter); some tradespace exists in length and weight. Non-mechanical beam steering designs, such as those incorporating electronically-scanned array antennas, and technologies which reduce size, weight and power requirements should also be explored, although the contractor is encouraged to pursue other unique designs. Additionally, the seeker modes should cooperatively hand-off target acquisition as the range of the target decreases. A fast scanning ladar achieves a high degree of spatial resolution to aid in target acquisition and classification, especially in the presence of background noise and clutter. Full-waveform analysis of multi-hit ladar returns is necessary to penetrate concealed targets, under both natural and man-made obscurants. It is not necessary to consider navigational/guidance technology for the seeker at this time.

PHASE I: Investigate the potential for hybrid designs of dual-mode (ladar/RF) seekers consistent with size, weight and power requirements of an extended-detection range flex/modular air-launched weapon for SEAD/DEAD missions. Bidder should propose a solution for resolving target images from multi-hit ladar data, making use of foliage penetration (FOPEN) and other advanced ladar processing techniques.

PHASE II: Develop complete dual-mode seeker technology demonstrator that meets objectives of the seeker requirements (stand-off detection range, LADAR imager scene size, etc.). Implementation of necessary signal processing algorithms to be made available as a deliverable. Show ability to resolve likely targets from background clutter.

PHASE III DUAL USE APPLICATIONS: Commercialize for law enforcement, marine navigation, commercial aviation enhanced vision, medical imaging venous and dermatological applications, and industrial semiconductor and manufacturing process control. Desirable per unit cost in volume should be < $100K.

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KEYWORDS: Ladar, RF, Dual-mode, seeker, hand-off, low-probability of intercept, LPI, SEAD, DEAD, FOPEN

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AF141-137 TITLE: Divert and Attitude Control System Technologies for Small Missile Applications

KEY TECHNOLOGY AREA(S): Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop/demonstrate innovative technologies for light-weight, affordable and capable DACS for endo/exoatmospheric Air Superiority Interceptors. Designs should reduce cost & maintenance, improve manufacturability, and improve reliability.

DESCRIPTION: Current technologies exist for Divert and Attitude Control Systems (DACS) used large ground-launched air superiority missiles; however, these systems have the benefit of large diameters making packaging of the control systems relatively easy. Additionally, higher cost subsystems are tolerated due to the missiles' strategic nature and the fact that they are procured in relatively small numbers. Use of exotic, expensive, and/or difficult to manufacture materials/components would be cost prohibitive on tactical missile systems that will be purchased in the thousands.

A need exists to develop an affordable, high performance, light weight DACS for use in an air-launched, nominal 5" to 7" diameter, <300 lb air superiority missile. Enhanced missile agility is required to provide off-axis intercept capability to enlarge the target no-escape zone. Divert and Attitude Control System technologies have the potential to provide future missiles with unprecedented maneuverability without degrading beyond visual range performance. Advanced technologies are needed to address cost reduction, manufacturability, and reliable system design while maximizing the total impulse available within the volume of the DACS subsystem in an air-launched air superiority missile application.

Innovative development in the following enabling technology area is desired:

Component Design/System Architecture: Innovative concepts for affordable, lightweight, high-performance DACS for use in air launched air superiority missiles are desired. Such DACS will not exceed a volume of 250 cubic inches in a nominal 5" to 7" diameter missile, will not exceed a weight of 30 lbs, will maximize the total impulse available within the volume of the DACS subsystem, will allow for variable impulse maneuvering, will allow for a high degree of angular resolution, and will meet temperature and loading robustness requirements for use in an air-launched, nominal 5" to 7" diameter, <300 lb air superiority missile.

PHASE I: Develop a proof-of-concept design; identify candidate materials, designs and test capabilities, and conduct feasibility assessment for the proposed divert/attitude correction technology. Define proof of capabilities test concepts. Results from the design and assessment will be documented for Phase II.

PHASE II: Build a breadboard and/or prototype of the proposed concept. Demonstrate the merit of the concept through a combination of detailed analysis, digital simulation, laboratory tests, and/or testing in actual operating conditions.

PHASE III DUAL USE APPLICATIONS: Developed technology should have direct insertion potential into missile defense systems. Conduct engineering & manufacturing development, test & evaluation & hardware qualification. Demonstrate to include demonstration in system-level testbed w/insertion into air-launched air superiority missile.

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KEYWORDS: interceptor, actuator, diverter, DACS, control system

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AF141-138 TITLE: High Density Carriage Technology Innovation

KEY TECHNOLOGY AREA(S): Weapons

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OBJECTIVE: Identify and evaluate innovative ideas/concepts of external, bay, or otherwise significantly mission-efficient (logistics, platform load out, expanded envelope, selectable effects-compatible, cooperative/multiple release, etc.) system technologies.

DESCRIPTION: Current weapon employment mechanisms generally employ, gravity-release, gas-driven ejection by piston or tube, or mechanically extended trapeze-racks to provide safe and effective weapon employment. Current legacy weapons have fins and guidance modules, are generally round, and are only rated for carriage and release on certain bomb rack mechanisms. This limits flexibility to carry mixes of air-to-air and air-to-ground munitions for a particular mission set. Current products using these technologies do not meet the performance needed for current and future aircraft to meet projected mission lethality and survivability requirements. This SBIR is structured to bring new ideas from small businesses to add to, or enhance, the U.S. weapon carriage industrial base.

The most attractive technology attributes include: more weapon capacity; mechanisms & software to enable/enhance full-spectrum platform survivability; and that expand weapon employment envelopes (Mach, maneuver, turbulence, or direction of employment) or allow new trade space (size, weight power, location) in future aircraft designs. This topic can accommodate a wide range of innovation in missile, bomb, and other weapon compressed carriage approaches to include guidance and control fins, weapon shape, racks/ejector/lugs, weapons cabling and aircraft interfaces to advance weapon carriage/employment state-of-the-art technology.

PHASE I: Investigate: The most attractive proposals communicate the proposed innovation with regard to the physical and environmental requirements of separation/employment and the scientific principles supporting the innovation. Phase I expected to address concept, interfaces and comm. Simulation and models address compatibility, structure, separation, air to air/ground, subsonic and supersonic delivery.

PHASE II: Develop and demonstrate: The most attractive proposals advance from investigation; communicate innovation mechanical, electrical, pneudraulic, and computer/software components. Address each phase of (sub) system operation, with respect to imposed/experienced forces, moments, velocities, and success parameters. Should include physical/mathematical models, simulations, demonstrations, and any static/dynamic tests, future or legacy/backward compatibility and integration with intended vehicle.

PHASE III DUAL USE APPLICATIONS: Demonstrate advanced packaging concepts with expanded ground testing, experimental flight test, manufacturability optimization, and appropriate advanced integration events and evaluations.

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KEYWORDS: Compressed carriage, Generation 5 aircraft, Generation 6 aircraft, small diameter bomb, AMRAAM, bomb rack, MILSTD 1553, MILSTD 1760, wireless, fiber optic, ejector cartdrige, tube launched, ejector cartridge

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AF141-139 TITLE: MWIR Seeker-Sensor for Strap Down Weapon/SUAS applications

KEY TECHNOLOGY AREA(S): Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop technologies leading to high operating temperature (HOT) wide field of view (WFOV) MidWave InfraRed (MWIR) miniature seekers for strap down weapons and small unmanned air systems (SUAS) applications.

DESCRIPTION: New high operating temperature (HOT) MWIR [1] detector material such as nBn, high temperature mercury-cadmium-telluride (MCT), and super-lattice detectors have raised the operating temperature and reduced the cooling requirement to the point where a compact, eighth of a watt cooler can provide background limited performance. Therefore, a path to higher operating temperature MWIR imaging seeker (with or possibly without) a very low power micro cryogenic cooler is apparent. Since resolution and detection range of uncooled infrared (LWIR) detectors and its long integration time of 10s of milliseconds is detrimental in high speed weapon applications, novel miniature MWIR seeker components are of interest to future high speed weapons. Other recent developments and demonstrations that make a miniature seeker feasible include wide field of view (WFOV) optical developments [2] based on biological inspirations [3], on-focal plane array processing (built-in the readout integrated circuit (ROIC)) or "SMART" (also bio inspired) FPAs [4], and vision chips with a variety of built-in image and signal processing functions [5, 6]. Demonstration of 10 micron pitch in the MWIR [1] allows for spatial oversampling which provides benefits in sensitivity and detection [7]. It has long been known that there are numerous advantages to sampling images hexagonally rather than rectangularly. Recent demonstrations in the efficient processing of hexagonally sampled imagery [8] now make the utilization of hexagonal imagers feasible. The Weapon Engagement Division of AFRL's Munitions Directorate is interested in exploiting the latest developments from the HOT MWIR and biologically inspired optics and imagers community for demonstration of a miniature WFOV seeker technology (to include sensor and processing components) leading to a strap-down gimbal-less seeker for air-to-ground strike high-speed weapons and small unmanned air systems (SUAS) applications. We are especially interested the development of biologically inspired WFOV optics and imagers, higher than 77 Kelvin detector technology coupled to readout integrated circuit (ROIC) unit cell circuitry that optimizes the HOT detector performance. high frame rate variable acuity ROIC architectures, mixed signal analog-digital ROIC architectures with built in temporal-spatial processing, rectilinear or hexagonal imaging array optimized to WFOV optics, compact imager control electronics for tightly coupled imager control and built-in processing for imager aided guidance, navigation, and control.

For weapon and SUAS seeker applications, bigger imager format is not always better, but higher frame rate is. We are interested in a systems engineered design and integration utilizing the recent infrared imaging technologies described above.

PHASE I: Determine the feasibility of the proposed seeker concept, and develop a design suitable for fabrication. Identify critical components that make up a MWIR WFOV miniature weapon seeker. Prioritize further development of any identified component, i.e. HOT detector and its associated ROIC, WFOV optics, rectilinear or hexagonal imaging array optimized to optics, ROIC with on-ROIC “smart” processing.

PHASE II: Develop prototype components and instrumentation that will lead to the demonstration of a family of miniature MWIR seekers that possess more integrated on-chip capabilities than are now available. Show, through demonstration, how these devices may be applied to important military applications such as weapon seekers or for collision avoidance of micro air vehicles. Communication between phase II selected component developers for up front interface/integration is a plus.

PHASE III DUAL USE APPLICATIONS: Military Application: Transition into current precision guided munitions, AF SUAS, targeting, small weapon seekers, and persistent surveillance applications. Commercial

Application: Possible uses include surveillance, astronomy, mapping, weather monitoring and earth resource monitoring.

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KEYWORDS: high operating temperature, HOT, wide field of view, WFOV, mid wave infrared, MWIR, biologically inspired optics and sensory processing

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AF141-141 TITLE: Weapons Effects FRMs for Contact or Embedded detonations in Fixed Targets

KEY TECHNOLOGY AREA(S): Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop innovative High-Fidelity Physics-Based (HFPB) Fast-Running Models (FRMs) for simulating the effects of weapons detonated on contact or embedded in fixed target structural materials.

DESCRIPTION: Damage to fixed structures resulting from the intentional or accidental detonation of weapons upon contact or when embedded often results in hazards to nearby personnel, equipment, and structures. Currently AFRL/RWWL's Modular Effectiveness Vulnerability Assessment (MEVA) program does not have the capability to predict these types of problems. In addition, other commercial and military organizations need FRMs that predict the structural damage and characteristics of debris generated by these events. The penetration, perforation, and breach of these structures by munitions involve multi-phase, multi-flow physics that has just recently been adequately modeled in HFPB codes. What is now required by analysts and weaponeers alike are innovative FRM methodologies that are based on these HFPB codes but can be executed without the time penalty associated with them. These users do not have the expertise or the time required to run HFPB calculations do to their need to execute hundreds, if not thousands, of these calculations in very short periods of time.

Consequently, the primary requirement is to develop fast-running models based on HFPB analyses that are representative of the HFPB analyses and have an overall accuracy of 80% or better when compared to actual test data. The primary structural damage parameters of interest include hole size and shape, rebar damage, mass and velocity of the debris generated, and residual capacity of the damaged wall. The models must represent both partial and full penetration of the structural materials and the possible detonation of these weapons upon impact or after partial penetration. The key technology areas are Weapon-Target Interaction, Target Penetration, Impact & Delayed Detonation, Back Face Spalling, and Debris generation.

Back face spalling of the target materials, including fragment size and velocity (vector) distributions are of interest, particularly as they affect human and equipment vulnerability. The end states of weapon-generated rubble (quantity and spatial distribution) are also desired.

When damage levels are sufficient to result in perforation(s) of the structural component, the model must predict the hole size(s) and volume of material removed. The model must output probabilistic debris fragment size and velocity (vector) distributions and debris end-states (quantity and spatial distribution of the debris on the ground). The models must be validated against available experimental data with recommendations for additional testing where sufficient data does not exist for adequate validation.

When damage levels are not sufficient to result in perforation of the structural component, the model must be capable of predicting the depth of penetration, the effects of any explosive charge including debris generation, the probabilistic distributions of debris fragment size and velocity, and rubble end state. The model must cover materials such as concrete and masonry (CMU, Brick, Adobe, Tile) used in fixed structures.

The predictive accuracy of the models must be quantified, based on comparisons with experimental data and HFPB calculations. Finally, the contractor must implement the FRMs in AFRL/RWWL’s MEVA architecture which is used for assessing the lethality of conventional weapons. To this end, MEVA will be provided along with the necessary integration instructions. If necessary, access to the MEVA developer will be provided or he can be hired to do the integration.

Other users include the Army (ARL & AMSAA), AFLCMC, and JTCG/ME. Following this effort, the government will install the FRMs in the AFLCMC FIST program and finally in the JTCG/ME JWS weaponeering program.

PHASE I: Develop innovative FRM methodologies that can be trained by state-of-the-art HFPB calculations to simulate the effects of weapon contact or embedded detonations in fixed targets. Demonstrate their ability to capture the important characteristics of these multi-physics phenomena.

PHASE II: Develop FRMs to simulate the effects of weapon contact or embedded detonations in fixed structures constructed of concrete & masonry material. The FRMs must capture the important characteristics of the phenomena for a parameter space spanning weapon type and size, and structural geometry and materials of practical significance. Implement these models in the AFRL MEVA program.

PHASE III DUAL USE APPLICATIONS: Military: Complete the development of the FRMs for the range of weapons and structural components/materials required. Commercial: Used by HAZMAT teams to asses safety for explosive materials. Used in assessing safety of buildings designed for protection against natural and terrorist threats.

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KEYWORDS: Weapon-Target Interaction, Target Penetration, Impact and Delayed Detonation, Debris Generation, Weapons Simulations, Fixed Targets, Structural Response, MOUT, Urban Targets, Weapon Lethality, Target Vulnerability, Engineering Models, Fast Running Models, Finite-Element Models, Debris Modeling

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AF141-142 TITLE: Plug and Play for Architecture for Modular Weapons

KEY TECHNOLOGY AREA(S): Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop novel interface hardware & protocols for integration of weapon seeker, sensor, fuzing, guidance and control. Investigate plug & play open architecture for rapid evolution of new seeker, guidance units, & fuzing for multi-role munitions.

DESCRIPTION: Current legacy weapons are tightly integrated "stove-pipe" closed architectures. Technology innovation to improve weapon performance, increase mission effectiveness, reduce acquisition cost, and extend weapon support lifetime are often negatively impacted by unique proprietary weapon data interconnect architectures. This topic is to investigate an open architecture "plug and play" concept for the communication, guidance and control, fuzing, and safe and arm functions along with communications to the aircraft or ground controller (weapon -aircraft interface and weapon data link). This will consist of building a technical framework that will begin by defining several open interfaces for a BUS system to connect the communication, guidance and control, fuzing, and safe and arm functions together. This will be the basis for a technical framework that will be developed. From this technical framework a technical service oriented architecture will be designed in a current software modeling language. Each service will be unassociated, loosely coupled units of functionality that are self-contained. Ultimately this will allow simultaneous use and easy mutual data exchange between modules of the weapon developed by different vendors without additional programming or making changes to the services.

By example new improvements in fly by light transponders and environmentally rugged fiber optics provide opportunities to replace costly and delicate cable/connector assemblies. Kalman and optimally filtered guidance schemes provide for novel opportunities to mix and match inertial, seeker, and GPS inputs instead of tightly integrated stove pipe guidance schemes of the past. New secure wireless network technologies may provide opportunities for minimal cabling through the aircraft bay, racks and pylons providing maximum flexibility for which type of weapon can be carried on a particular rack. Investigate functional equivalents for MILSTD 1553 and 1760 protocols along with new "broadcast Remote Direct Memory Access" RDMA and precision time protocols that would support rapid addressing multiple weapons at the same time.

The goal is to provide the ability to develop weapons components, guidance law software and processors, target recognition and track modules, attitude and control units, seekers and sensors and be able to integrate rapidly technology from various sources in response to new and evolving user needs. An example would be to re-utilize a seeker from an current weapon on a new weapon without extensive redevelopment time and cost.

PHASE I: Investigate critical components to demonstrate a robust plug and play framework for weapon systems. This framework should address various open interface standards from Optical to Wireless. Various use cases should be developed and defined. Estimate cost,size, and weight savings over current cabled weapons systems and racks. Determine interfaces to legacy weapons and launcher systems.

PHASE II: Develop and demonstrate a modular weapon open interface architecture based on the framework developed in Phase I. This should include both seeker and guidance and Control modules. Functional and system testing of the architecture will be used to verify the architecture against the design documents and specifications developed in Phase I. The use cases developed in Phase I will be turned into test cases to provide traceability throughout the development.

PHASE III DUAL USE APPLICATIONS: Working with DoD weapon primes, develop and demonstrate flight functional units and provide live drop testing showing accuracy, performance, and long term logistical cost savings to the U.S. government.

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KEYWORDS: Plug and Play, IEEE1588, Broadcast RDMA, FLEX Weapon, F-35, F-22, Bomb Rack

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AF141-143 TITLE: Data Analysis and Mining for Penetration Environment Dynamics (DAMPED)

KEY TECHNOLOGY AREA(S): Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop innovative analytic tools to describe the stochastic/probabilistic features of the penetration fuze environment and analyze using data mining from diverse experimental and computational data sources.

DESCRIPTION: The operational dynamic environment for hard target fuzes is known to be exceedingly harsh. The environment is typically characterized as having long duration, high amplitude, high frequency content, impulsive loading characteristics (i.e., shock-like). The loading is also multiaxial and typically involves several repeated impulses (i.e., repeated loading cycles). Finally, the penetration dynamics are anything but repeatable, even nominally identical test events can have orders-of-magnitude difference in severity, both quantitatively and qualitatively. This is due (at least in part) to natural variations in the weapon systems (assembly and materials), targets (strength, geometry, etc.), and a host of other contributing factors (such as incident attitude of the weapon). All of these factors support the assertion that hard target fuzes experience a harsh, complex, stochastic environment.

While several individual metrics/figures-of-merit have been proposed and used to describe the environment, it is beyond the current state-of-the-art to completely parameterize and describe in a probabilistic sense (e.g., using the joint probability distribution) the various aspects of the mechanical environment that are relevant to evaluating fuze survivability and lethality. Additionally, the survivability of a given fuze system in a range of weapon systems and/or operational target engagement scenarios must also be considered and described using this same probabilistic language. Given the high dimensionality (i.e., the number of contributing parameters is >>10), it is impractical from a resource or schedule standpoint to build this information using test data alone. However, combining empirical and computational simulation data can provide valuable insight into the environment, and both sources of data need to be assimilated. (Note: Available test and simulation data will be provided as government-furnished information at the initiation of the contracted effort.)

This SBIR topic seeks to develop and mature the language and analytic tools necessary to describe this environment in a probabilistic sense and improve the accuracy (i.e., the predictive power) of simulations. It is expected that this effort would lead to the development of tools and submodels that evaluate the mission-level performance/effectiveness (i.e., survivability, reliability, and lethality) of a fuze design for arbitrary operational scenarios. The long-term vision of this effort is to establish a new paradigm for evaluating the design margin of fuzes in operational environments, complementing empirically-based methods such as the Fuze Survivability Protocol with probabilistic modeling tools.

Note: The data, analysis methods, and results are expected to be classified at or above the Secret level.

PHASE I: Define analytic techniques to describe the fuze environment. Document and develop interface information on data sources and formats, including both experimental and simulation. Apply methodology to empirical laboratory-scale shock test data to demonstrate viability of approach.

PHASE II: Refine analytic toolset to accommodate diverse sources of information. Perform analysis on all available information for an inventory legacy penetrating weapon system and write document summarizing environment. Develop user interfaces and optimize data management to ensure usability.

PHASE III DUAL USE APPLICATIONS: Develop campaign-level weaponeering tools (e.g., compatible with IMEA) based on tools and analysis developed in Phases I and II.

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KEYWORDS: fuzes, hard target fuzes, harsh environment, stochastic modeling, weapons, testing, acceleration, fuze testing, test methods, multiaxial loading

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AF141-144 TITLE: Cooperative RF Sensors

KEY TECHNOLOGY AREA(S): Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop cooperative RF sensor systems that improve operations in the A2AD environments, including low probability of intercept; resistance to interference; and, greater flexibility in accomplishing assigned missions with reduced time line.

DESCRIPTION: The future of radar sensors will be software defined and have flexible missions. They will need to operate cooperatively in hostile environments and meet the demanding cost, size, weight and power (CSWaP) constraints of weapons for 5th- and 6th-generation platforms in all-weather conditions. Furthermore, in the Anti Access/Area Denial (A2AD) environment, the survivability and effectiveness of the munitions during ingress is crucial. Cooperative radar sensors will have beneficial characteristics for improved operations in the A2AD environments, including low probability of intercept, resistance to interference, and greater flexibility in accomplishing assigned missions with reduced timeline.

Due to the size constraints (9" diameter), and required operating ranges (> 10 Km), cooperative RF sensor systems are expected to operate in the Ku or Ka bands. In order to accomplish this, advanced digital signal processing techniques will be required to implement the adaptive clutter and interference mitigation algorithms and/or form synthetic aperture radar imagery. With the overall goal of being able to achieve 1-foot range and cross range resolution in the cooperative SAR mode.

PHASE I: The Phase I study should determine the feasibility of the cooperative RF sensor techniques and implementation strategies. System performance requirements for cooperative RF sensor concepts should be considered and translated into design specifications. Trade-off analysis and simulation of critical performance parameters is expected during Phase I.

PHASE II: Determining the requirements for the algorithms to process the RF data collected in a cooperative scenario. Refine the system requirements developed in Phase I using the results of the trade-off analysis. Develop and demonstrate the cooperative RF algorithms with simulated and/or real data. Tune the algorithms to maximize performance and develop the concepts of operation for cooperative RF sensors.

PHASE III DUAL USE APPLICATIONS: Build prototype and perform demonstration of cooperative RF sensor system. Commercialization potential exists for automated vehicle navigation techniques.

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KEYWORDS: Radar, RF Sensor, Cooperative

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AF141-145 TITLE: Electromagnetic Effects in Energetic Materials

KEY TECHNOLOGY AREA(S): Weapons

OBJECTIVE: Use electromagnetic (EM) fields to alter the properties or combustion of energetic materials. Exploit these effects for real-time control of sensitivity, energy release, or power release, or greater lethality from combined kinetic-EM effects.

DESCRIPTION: The primary objectives are to understand and control sensitivity thresholds, energy release, and/or power release from energetic materials using electromagnetic (EM) fields, and to exploit this for selectable kinetic effects or combined kinetic-electromagnetic effects.

The industrial community has used electromagnetic fields to control combustion in low-rate commercial processes, but there has been little work in energetic materials with higher combustion rates, i.e., propellants, pyrotechnics, and explosives. The need for real-time sensitivity and rate control is driven by the need for munitions that are more insensitive (i.e., safer), more flexible (i.e., tunable), and more lethal (i.e., enhanced effects).

User control of pre-combustion properties and/or energy release may require novel energetic materials and novel initiation techniques. This effort may involve development of new energetics that are sensitive to electromagnetic fields [1], exploitation of electromagnetic properties in existing energetics [2]), or doping existing energetics with EM-sensitive materials (e.g., photoresponsive additives). It may require novel initiation techniques -- external electromagnetic fields [3], shock from single or multipoint initiation sources, or some combination of the two. EM fields might be used to produce physical or chemical effects such as: mechanical strain, stress, or shear; localized ohmic heating (i.e., hot spot generation [3]); chemical changes [1]; or alterations in the energetic material's plasma chemistry or other property [4, 5]. Candidate materials include organic explosives, inorganic explosives (e.g., thermites, intermetallics), propellants, and pyrotechnics. The proposer might consider the effect of EM fields on different material phases (solid, liquid, gas, plasma, metallic glass, etc) and composite materials (e.g., doped or metalized explosives).

The physics and chemistry affecting sensitivity is poorly understood. The energetics community usually relies on empirically-determined “go/no-go” thresholds for combustion on-set. This approach provides vital safety criteria, but does not advance our understanding of how to control initiation thresholds and combustion processes in real-time. This project may need physics-based and chemistry-based models to understand the effect of electromagnetic fields on combustion, and novel instrumentation and diagnostic methods that provide spatial and temporal resolution of the physics and thermochemistry of electromagnetically-enhanced combustion. Model development and diagnostic development are important enabling technologies but these alone do not meet the objectives of this topic. There must be development of a concept that controls and exploits these EM-energetic effects.

For example, the EM-energetic effect might be control of combustion rate in energetic materials for a selectable yield weapon. The combustion regimes of interest include burn, deflagration, detonation, and overdriven detonation. [Note: The concept need not include all four regimes.]

This topic places no restrictions on the electromagnetic wavelength domain, but the proposal should discuss any design limitations, consequences, or adverse effects associated with the design choice, and whether the concept is compatible with the Hazards of Electromagnetic Radiation to Ordnance (HERO) standards. Although weaponization of an electromagnetic source is outside the scope of this effort (if an external source is part of the concept), the proposal should discuss the weaponization potential of the EM source -- power levels, miniaturization, thermal and shock hardening, etc.

This topic excludes explosive pulsed power devices (i.e., explosive flux compression generators (EFCG)) or EFCG-driven kinetic weapons. The topic does include technologies in which both kinetic and electromagnetic effects are combined for enhanced lethal effects on the target.

PHASE I: Develop a means to alter an explosive's properties or its combustion behavior with an electromagnetic field and a concept to exploit this effect for a selectable effect or enhanced lethality warhead. Use or develop physics-based and chemistry-based modeling. Small-scale testing to show proof-of-concept is highly desirable. Merit and feasibility must be clearly demonstrated during this phase.

PHASE II: Develop, demonstrate, and validate the component technology in a prototype based on the modeling, concept development, and success criteria developed in Phase I. Deliverables are a prototype demonstration, experimental data, a model baselined with experimental data, and substantiating analyses.

PHASE III DUAL USE APPLICATIONS: Military applications include insensitive munitions, enhanced lethality, selectable effect, and low collateral damage munitions. Commercial applications include variable-rate airbag inflation and low collateral damage weapons for DHS and law enforcement in sensitive urban scenarios.

REFERENCES:
1. Martin E. Colclough et al., "Novel Explosives," United States Patent Application 20100089271 A1, filed 18 February 2008.

2. Craig M. Tarver, "Effect Of Electric Fields On The Reaction Rates In Shock Initiating And Detonating Solid Explosives," AIO Conf. Proc., 1426, 227 (2012).

3. W. Lee Perry et al., "Electromagnetically induced localized ignition in secondary high explosives: Experiments and numerical verification," Journal of Applied Physics, 110, 034902 (2011).

4. G.O. Thomas, D.H. Edwards, M.J. Edwards, and A. Milne, “Electrical Enhancement of Detonation,” J. Phys. D: Appl. Phys., 26, pp. 20-30 (1993).

5. M.A. Cook and T.Z. Gwyther, "Influence of Electrical Fields on Shock of Detonation Transition," AF-AFOSR-56-65 (1965).

KEYWORDS: electromagnetic fields, energetic materials, explosives, propellants, pyrotechnics, fuels, thermites, intermetallics, sensitivity, insensitive munitions, lethality, variable rate, selectable effects, low collateral damage, plasma physics, thermochemistry, modeling, spectroscopy, detonation, deflagration, combustion

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AF141-151 TITLE: Engineered Process Materials for Casting of Aerospace Components

KEY TECHNOLOGY AREA(S): Air Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop casting mold materials and/or processes for the production of cast aerospace components with improved dimensional control and material properties through efficient heat transfer and thermal stress management.

DESCRIPTION: High performing turbine airfoils and structural components for turbine engines are typically produced via investment casting. Investment casting molds are created by successive iterations of slurry dipping, stucco application and hardening over a wax replica of the final casting geometry. These ceramic molds (or shells) are typically designed to (1) minimize structural failure of the mold prior to solidification, (2) provide sufficient casting surface finish and (3) crush during cool down to minimize stresses in the casting. Concurrently, casting core materials and processes (that ultimately provide internal features in castings) have matured separately from investment molds, limiting integration of the two processes in order to achieve superior dimensional control of the final casting.

However, the baseline process and materials are not optimized for heat transfer or thermal stress management during solidification. These deficiencies lead to: (1) non-optimized dendritic structure, (2) limitations on castability of fine-feature geometries, and (3) dimensional tolerance stack ups that lead to design constraints particularly for thin walls and fine features. These processing shortfalls manifest in increased propensity of material defects, distortion, mold cracking (run out) and design limitations for minimum feature size and minimum wall thickness.

The AF is seeking to develop casting mold materials and/or processes for the production of turbine airfoils or structural components for turbine engines in which the mold can be locally tailored to improve heat transfer from the casting, reduce thermal stresses, and decrease minimum feature size. It is anticipated that the advancement of this technology will provide components with reduced dimensional variability, finer or thinner features, and reduced defects, ultimately providing enhanced cooling efficiency and thus increased thrust-specific fuel consumption, compared to today’s state-of-the art.

PHASE I: Develop prototype process/material and evaluate feasibility of proposed approach.

PHASE II: Refine the prototype process/material based on lessons learned in Phase I. Validate final process/material configuration in a production representative environment. Provide assessment of process/material benefits relative to the baseline technology.

PHASE III DUAL USE APPLICATIONS: The developed process/material could be directly applied to airfoils and structural parts required in the commercial aviation market.

REFERENCES:

1. R.C. Reed, The Superalloys: Fundamentals and Applications, Cambridge University Press, 2006.

2. M. McLean, Directionally Solidified Materials for High Temperature Service, London: The Metal Society, 1983.

KEYWORDS: aerospace castings, thin walled castings, solidification stress

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AF141-152 TITLE: Uncertainty Quantification in Modeling and Measuring Components with Resonant Ultrasound Spectroscopy

KEY TECHNOLOGY AREA(S): Materials / Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Define, develop, and execute an uncertainty analysis for the multi-physics modeling of the variation in resonant ultrasound spectroscopy (RUS) frequency due to damage accumulation in Ni-base superalloys.

DESCRIPTION: To be able to model accurately the resonant effect of multiple conditions (both material and geometry-based) simultaneously, propagation of uncertainty, due to model, material and measurement "errors", must be well understood. The application of numerical simulation models to quantify the variation in resonant ultrasound spectroscopy frequencies of Ni-base superalloy material subject to macro/microscopic damage raises questions as the confidence of the model results and what can be done to improve this confidence? Uncertainties may have many different sources or drivers. Some of these uncertainties are model related and some are parameter related. To be able to model accurately the resonant effect of multiple conditions simultaneously, uncertainty quantification and error propagation must be well understood.

PHASE I: Identify sources of systematic errors that affect the accuracy and precision in the RUS estimation due to model, material, and measurement. Perform sensitivity analysis of how the uncertainty in outputs can be allocated to different sources of uncertainty in inputs. Derive confidence limits to describe where the true value of the variable may be found. Identify areas of focus for Phase II.

PHASE II: Work with actual components to validate the conditions modeled in Phase I. Match measured resonances with modeled resonances to examine errors. Utilize other methods to examine variation. Generate or obtain samples demonstrating variation in microstructure and/or dimensions. Examine alternate RUS hardware configurations in Design of Experiments (DOE) format to examine effects of sensor variables.

PHASE III DUAL USE APPLICATIONS: Develop system prototype RUS inspection system and demonstrate in an production environment.

REFERENCES:
1. Uncertainty Propagation in Analytic Availability Models, Amita Devaraj, Kesari Mishra, Kishor S. Trivedi, 2010 29th IEEE International Symposium on Reliable Distributed Systems, pg 121-130.

2. Implementation of a Modern Resonant Ultrasound Spectroscopy System for the Measurement of the Elastic Moduli of Small Solid Specimens, Albert Migliori, J.D. Maynard, REVIEW OF SCIENTIFIC INSTRUMENTS 76, 1, (2005).

KEYWORDS: Resonant Ultrasound Spectroscopy, Uncertainty Quantification, Ni-base Superalloys, Microscopic Structural Damage, Macroscopic Structural Damage, Nondestructive Inspection

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AF141-153 TITLE: ITO Repair on Transparencies

KEY TECHNOLOGY AREA(S): Air Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Currently, there does not exist an adequate ITO repair. Develop methods for the production of transparent conductive materials that are durable and easily applied for repair of scratches in ITO on transparent substrates.

DESCRIPTION: Indium tin oxide (ITO) is a traditional material of choice for conductive transparent coatings for use in many current and future Air Force applications. Applications include the dissipation of and shielding from incident energy and electrodes for display technologies, opto-electronic devices, and harvesting solar energy. While current technologies meet desired metrics for sheet resistance and transmittance[1,2], ITO is not durable, easily applied, or cost effective. During the lifetime of the ITO coating, scratches and nicks develop and begin to degrade its performance. Current repair processes use time consuming, labor intensive processes which are only temporary, and reduce visibility in the repaired area and tend to chip or peel off, which requires reapplication, and often the surrounding ITO coating is further damaged.

When the size of the damaged area increases beyond an acceptable level, the entire coating must be replaced, which is expensive and increases aircraft downtime. Currently, this repair process includes the removal of the entire transparency and shipment to specialized facilities wherein the coating is stripped and reapplied in large vacuum chambers which is very costly, wastes a large amount of indium and requires specialized equipment. Although this approach successfully returns the part in pristine condition, it also requires several weeks or months to complete, considerable maintenance, inspection and combat recertification, during which time the aircraft is out of commission. In addition to down time, Indium is an expensive element that has seen an enormous price increase in the last 10 years and is being utilized more and more by the electronics industry. Currently, there is not a domestic source for indium[3], and there is a desire to decrease reliance on Indium.

Alternatives to traditional ITO repair may include, but are not limited to, novel ITO manufacturing techniques that lower cost and time of large area deposition and allow depot maintenance, and non-ITO /Hybrid approaches such as polymer composites, thin single wall carbon nanotube/graphene networks, or thin films of inorganic/organic hybrids. Application techniques amenable to depot conditions (ambient temperature, humidity, pressure) are preferred and may include spraying, or rolling in order to fill scratches or gaps that are problematic in typical ITO coatings.

This project will develop the capability to produce filler material for scratch repair in current ITO coatings.

Potential commercial applications of this technology could include the repair of cellular phone or computer touch-screens, which also require continuous transparent conductive coatings in order to function properly.

PHASE I: Develop an ITO repair material and process that meets current metrics for ITO; ease of application, quick and seamless repair of damaged areas. Meet metrics for ITO, prove durable and flat (roughness <1 mil). Demostrate a repair on an area of 5millimeters by 20millimeters; easily applied for scratch repair.

PHASE II: Phase II will focus on increasing the production capability and demonstrate the effectiveness of the material. The deliverable in Phase II will be 1 kg of material and the demonstration of scratch repair of a series of ITO coatings meeting the above requirements without scattering or loss of continuity. The scratches should represent different depths and widths.

PHASE III DUAL USE APPLICATIONS: Qualify repair procedures for field applications.

REFERENCES:
1. F.F. Ngato, et al., “Deposition of ITO Films on SiO2 Substrates,” Applied Surface Science, vol. 248, pp. 428-432, 2005.

2. Edwards, P. P.; Porch, A.; Jones, M. O.; Morgan, D. V.; Perks, R. M. (2004). "Basic materials physics of transparent conducting oxides". Dalton Transactions (19): 2995–3002.

3. U.S. Geological Survey, Mineral Commodity Summaries, January 2009 (76-77) “Indium”.

KEYWORDS: ITO repair, ITO, scratch, scratch repair, canopy, ITO film, ITO film repair, repair, processable, ITO, indium tin oxide, transparent, conductive, coatings, scratch

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AF141-154 TITLE: Conformal Conductivity Probe

KEY TECHNOLOGY AREA(S): Air Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: To develop a tool capable of measuring the conductivity of coatings and gap fillers (sealants) on surfaces with complex curves.

DESCRIPTION: The current point inspection tool (Tier I) that is used to inspect electrically conductive coatings on the aircraft is a waveguide cavity probe. The probe is an open-ended waveguide of defined length, that is excited on the feed end through a circular iris. When the open end of the waveguide is placed on a flat conductive surface, a cavity is formed. The Quality Factor (Q) of the cavity is measured and the conductivity of the terminating wall is calculated. Errors are induced when the surface being inspected is non-planar due to leakage around the gap created by the waveguide and the curved surface being inspected. It is desirable to have a device that can measure the conductivity of coatings and gap fillers on mildly curved compound surfaces.

The measurement device should be capable of determining surface conductivity (ie: ohms per square) of conductive coatings and gap fillers. It is desirable to measure this within the 8-18 GHz frequency band, though not necessarily across the entire band. A single broad-band probe is highly desirable. The probe will be used on fielded air vehicles and cannot damage the surface being measured. The device should pose no safety hazard to personnel or equipment. It shall be capable of being approved for flight line operation. The surface will not typically be flat and therefore should conform to the surface being tested. Assume that the probe must accommodate surfaces from flat to a compound radius of curvature of approximately 50 inches. The equipment should also have the ability to support higher radii of curvature. The probe should be capable of measuring small areas to support gap filler inspection. A smaller footprint is desirable. It is anticipated that the probe will work in conjunction with a government furnished vector network analyzer. The analyzer is a two port instrument and it is desirable that the probe not require additional ports. A standalone device or one that utilizes special test equipment is acceptable. It is expected that this probe will be transportable and operable by a single technician. Considerations during the design of any equipment used for this end should include: robustness, hand held use in the field, and Class I, Div II certification.

PHASE I: Investigate concepts that may be applicable to non-destructive, in-situ evaluation of the electrical conductivity of gap fillers. The range of conductivity shall be between 0 to 10 ohms/square. It is be desirable for the technique performed through a thin dielectric coating. Demonstrate a measureable approach on a test panel with a 0.25" wide by 0.25" deep by >6" long filled gap.

PHASE II: Ruggedize equipment, workout commercialization issues, partner with any appropriate companies to ensure successful production, meet other needs of the user. Demonstrate hand-held, ruggedized version to be fielded.

PHASE III DUAL USE APPLICATIONS: This conformal conductivity measurement technology is expected to be used on military aircraft with conductive coatings and curved surfaces. Commercial use could include any measurement of electrical properties on curved surfaces.

REFERENCES:

1. Measuring the Resistivity of Bulk Materials, EE Times, Mary Anne Tupta (http://www.eetimes.com/ContentEETimes/Documents/tupta_eeteujan2011.pdf).

2. Dielectric Materials and Applications, Von Hipple.

KEYWORDS: conformal conductive probe, conductive measuring, gap filler conductivity measurement, conductive, measure, gap filler, gap, sealant, conductivity, probe, conformal probe

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AF141-156 TITLE: Vibration Stress Relief

KEY TECHNOLOGY AREA(S): Air Platforms

OBJECTIVE: Develop a repeatable technology to relieve stress in a weldment using vibration stress relief. The AF currently doesn't have many ways to repair large weldments and this process may provide the ability to repair major structural components.

DESCRIPTION: Vibration Stress Relief is gaining momentum in heavy industry as a way to reduce the residual stress built up during the welding process. If the processes currently established in industry can be shown to be mature, repeatable and controllable then the potential exists to perform on-airplane stress relief of weld repairs greatly increasing the reparability of the F-22 titanium frames and the forward and aft booms. Currently these structures cannot be weld repaired due to the required high temperature thermal stress relief process. Thus repairs often involve material removal and patches, causing more downtime and elaborate repairs.

This task could have great benefit to the customer in allowing them to perform on airplane weld stress relief. The US Department of Energy has said that vibration stress relief is a, "proven substitute to 80-90% of heat treat stress relief applications yet saves 65-95% of the time and cost in doing so without sacrificing quality!" A quick investigation of the Boeing Library indicates that it was last investigated in 1987 where it was shown to have promise but was not yet repeatable. Discussions with vendors indicate that the process has greatly matured in the subsequent 25 years [1-3].

PHASE I: Assess the reliability of a vibration stress relief (VSR) process to relieve the weld-induced stresses in a Ti-6Al-4V weldment using a reliable measurement technique, e.g., X-Ray diffraction, to characterize surface stresses before and after stress relief. Gauge R&R methods should be applied to both the process and the measurements to validate the VSR process effectiveness.

PHASE II: Expand the applicability of VSR to a broad spectrum of prototypical weld configurations / structural applications and develop a strategy to mature the technology to meet aerospace quality weld requirements at the fleet level. Demonstrate the effectiveness of VSR to improve the weld integrity to ensure improved mechanical performance and structural durability over untreated welds.

PHASE III DUAL USE APPLICATIONS: Develop and transition to industrial practice a validated, turnkey VSR process / system that can be applied to the weld repair of aerospace structural components to meet Air Force and OEM requirements. This should be demonstrated on real DoD or commercial hardware, e.g., Fighter Aircraft

REFERENCES:
1. A. Walker, A.J. Waddell and D.J. Johnston, Vibratory Stress Relief - An Investigation of the Underlying Process, Proc. Inst. Mechanical Engineers., 209, 51-58 (1995).

2. D. Rao, J. Ge, and L. Chen, Vibratory Stress Relief in the Manufacturing the Rails of a Maglev System, J. of Manufacturing Science and Engineering, 126, Issue 2, 388-391 (2004).

3. B.B. Klauba, C.M. Adams, J.T. Berry, Vibratory Stress Relief: Methods Used to Monitor and Document Effective Treatment, A Survey of Users, and Directions for Further Research, Proc. of ASM, 7th International Conference: Trends in Welding Research 601-606 (2005).

KEYWORDS: vibration stress relief, weldments, residual stress

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AF141-157 TITLE: Galvanic Corrosion Prediction for Aircraft Structures

KEY TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Develop a quantitative test method to characterize proposed material/material couple and a predictive tool to reliably identify the location/s and rate of galvanic corrosion for dissimilar materials/barriers under controlled environmental conditions.

DESCRIPTION: Predicting galvanic corrosion is a high priority for USAF aircraft system managers. However, there are currently no design trade tools available to aerospace engineers that effectively characterize the behavior of common airframe construction materials and account for their contributions to galvanic corrosion. Obtaining such a tool is critical during design of new aircraft structures as well as legacy airframe repair material selections as a means of moving from the philosophical goal of “find and fix” to a presumably more cost-effective “predict and manage.” This necessitates development of novel trade tools which can predict the galvanic corrosion-specific performance of common structural materials, fastening, and proposed barrier scheme/s. The tool will allow designers the ability to validate material selection, providing prediction and economical life cycle management of the weapon system.

PHASE I: Illustrate feasibility by developing and demonstrating a prototype tool to quantify material couples & predict galvanic corrosion. The materials will be bare aluminum (7050-T7451) & graphite epoxy composite. Quantitatively compare the tool with actual test data to reliably identify "hot spots." Quantitative analysis could include but not limited to weight loss, micrograms/cm2/year.

PHASE II: Implement best approach from Phase I into a prototype tool capable of quantifying and predicting galvanic corrosion in a representative mechanically fastened and/or bonded joint constructed from typical materials and processes. The AF is interested in a tool associated with 7050-T7451 anodized aluminum bonded with Hysol EA 9394 epoxy paste adhesive to graphite epoxy. Deliverable of final report shall include recommended practices for predicting galvanic corrosion for design of AF systems.

PHASE III DUAL USE APPLICATIONS: Phase III commercialization opportunities abound with aerospace manufacturers and DoD laboratories. Industry needs to ensure sustainable designs do not have undue corrosion while the sustainment methods maintainers incorporate do not lead to additional galvanic corrosion.

REFERENCES:
1. P. Poole, A. Young, and A.S. Ball, “Adhesively bonded composite patch repair of cracked aluminum alloy structures,” in “Composite repair of military aircraft structures,” AGARD-CP-550, October 1995, Paper 3. (http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA293056#page=37).

2. H. P. Hack and J. R. Scully, “Galvanic Corrosion Prediction Using Long- and Short-Term Polarization Curves,” Corrosion, February 1986, Vol. 42, No. 2, pp. 79-90. (http://corrosionjournal.org/doi/abs/10.5006/1.3584889).

3. M. Mandel, L. Krüger, “Determination of pitting sensitivity of the aluminium alloy EN AW-6060-T6 in a carbon-fibre reinforced plastic/aluminium rivet joint by finite element simulation of the galvanic corrosion process”, Corrosion Science, 2013. (http://www.sciencedirect.com/science/article/pii/S0010938X1300125X).

KEYWORDS: corrosion, galvanic, bonded composite

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AF141-158 TITLE: Durable, Low Friction Coating for Variable Speed Refueling Drogue (VSRD)

KEY TECHNOLOGY AREA(S): Air Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop and demonstrate a durable coating that can be applied to the MC-130J's VSRD outer ribs in order to increase the mean time between failures and reduce life cycle cost.

DESCRIPTION: The Variable Speed Refueling Drogue (VSRD) is used on the MC-130J to refuel helicopters with probe-and-drogue refueling systems. The program objective is to develop a sustainable, suitable, and cost effective aerial refueling drogue for the 37 MC-130J Commando II aircraft. The new VSRD system will be capable of supporting an airspeed envelope of 105-210 Knots Indicated Airspeed (KIAS), providing aerial refueling support for SOF CV-22 and rotary-wing platforms.

The current VSRD coating wears off after about 250 cycles and creates a problem where the drogue will get stuck in the refueling pod storage tube, thus precluding the MC-130J from performing its intended refueling mission. The thirty year life cycle estimate for rib replacement due to coating wear-out for the entire MC-130J fleet is approximately $112 million. The MC-130J program office is looking for a more durable, low friction material to recoat the rib. This would help extend the VSRD mean time between failures. The program office estimates that this will lower the life cycle cost to approximately $43 million.

The purpose of this SBIR effort is to overcome the above deficiencies by developing a new, more durable material that can facilitate the drogue entering and exiting the refueling storage tube for the drogue.

There are many different types of coatings in industry, but none has the functionality needed for the harsh operating conditions in which the VSRD is used. The contractor that developed the VSRD researched and tested about eight candidates and determined that a Keronite base coat with a Xylan 1088 top coat provided the best combination of durability and low friction.

What is needed is a coating which can withstand more cycles scraping against screw heads and the inside of the refueling pod storage tube and have a low coefficient of friction. The new coating must be able to be applied by field maintenance personnel to 6XXX series aluminum without the need for special equipment to apply or cure the coating.

PHASE I: Define the coating requirements. Identify appropriate coatings for evaluation. Develop sample batches of potential coatings. Apply coatings to typical VSRD aluminum substrates. Perform laboratory validation to demonstrate/validate friction and wear performance. Downselect coatings to be demonstrated during Phase II.

PHASE II: Apply the coating to a Variable Speed Refueling Drogue (VSRD) and test it in a relevant environment. Demonstrate field application. Develop production quantities of coating. Expected Technology Readiness Level of the coating by the end of Phase II is TRL 6, and preferably TRL 7.

PHASE III DUAL USE APPLICATIONS: Military Application: Air refueling pods; equipment that requires continued maintenance due to friction between control surfaces. Commercial Application: Industrial equipment where there is frequent contact between mechanical parts that leads to erosion of components.

REFERENCES:

1. http://www.cobham.com/media/847796/variable_drag_drogue_datasheet.pdf.

2. http://www.wordiq.com/definition/Aerial_refueling.

KEYWORDS: Refueling, abrasion, coating

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AF141-159 TITLE: Portable Drill-Fastener

KEY TECHNOLOGY AREA(S): Air Platforms

OBJECTIVE: Develop a light weight, standardized, robust, affordable, portable drilling system capable of inserting fasteners and torquing associated nuts. The design should allow for growth (e.g. - insertion and upsetting of rivets for final installation).

DESCRIPTION: Legacy sheet metal aircraft such as the C-130J have hundreds of thousands of fasteners with the vast majority drilled and installed by hand, one at a time. This work is labor intensive, increases the production span of aircraft, generates repetitive motion injuries, and is a source for quality issues. The manual drilling process requires other steps during the assembly operation including de-stacking the assembly, de-burring individual holes, applying sealant to the parts if required, reassembling the parts and wet installation of fasteners with sealant. Completing the fastener installation requires setting the torque for the threaded fastener nuts. Traditional fastener installation machines are very large, heavy, expensive, and immobile systems which perform the drill-fasten operation without the de-stack and de-burr processes. Major drawbacks to the traditional systems are: they are dedicated to a limited number of parts which greatly restricts the possible applications, they cannot access confined spaces, and they fall into the category of capital equipment.

The envisioned system shall be capable of drilling, installing and setting threaded fasteners in common aircraft alloys on legacy aircraft assemblies in a production environment. As a possible future adaptation, consideration shall be given to the installation and upsetting of rivets. The system will be affordable, portable, and easy to integrate. It should be hand-held, with a target maximum weight of 15lb. Solutions that are heavier will be seriously considered if they offer a valid approach, for example, if the heavier system is supported by a tool balancer. The system should be priced low enough to allow it to be purchased in large quantities and to be applied across multiple applications/programs. The current target price for the hand-held tool is $30K but can increase based on the capabilities of the tool. An initial cost benefit analysis of any solution shall be performed near the end of the Ph II effort. The intent is to be able to drill and install fasteners in various assemblies with a common tool. The system must be able to accomplish these tasks without the de-stack and de-burr processes while producing a high quality hole. The system shall also be easy to maintain and utilize common components wherever possible.

The expected output of the Phase I and Phase II topic is a prototype system that will be considered for implementation and therefore, needs to meet manufacturer specifications. It is highly encouraged that offerors are willing to work with and have a letter of support from the system OEM. Detailed specification information is proprietary but more information will be made available following Phase I and Phase II awards. The outlined tasks are: locate hole (through sheet metal template or pilot hole), provide sufficient clamp force to eliminate delamination during drilling which prevents inter-laminar burrs, drill through stack-up, apply sealant, insert fastener, retain fastener (upset rivet or thread on a nut). The maximum allowed burr on the exit side of the hole is 0.002". The requirement on sealant is that there must be a witness of sealant squeeze out under the head and the tail of the fastener. Torque accuracy requirements for application of nuts is +-4% + 2in-lb. Rivet tail requirement is tail height must be equal to 1 diameter and the tail diameter must be at least two diameters.

Numerous companies in the aerospace industry provide high quality, self-feeding, portable, drilling systems, some of which possess the capability to provide clamp force usually through the mechanism of a pneumatic cleco. There also exists hand held automatic fastening systems capable of running nuts on threads from a preloaded “magazine”. The new technology would marry these two existing capabilities along with an automated fastener insertion device, and sealant applicator to create a complete single pass drill and fill operation.

The fasteners are standard MS rivets and interference fit HI-Tigue threaded fasteners. It is not expected one unit to be able to install both rivets and threaded fasteners. It should be assumed that separate units will be used for the different fastener types.

PHASE I: The focus of Phase I will be a feasibility study and the development of a preliminary design(s) for a Portable Drill-Fastener System. Initial estimates of unit size, weight, capabilities, and single unit cost are expected. Unit fabrication (prototyping) is not expected in Phase I.

PHASE II: Phase II will be on the selection of a design from Phase I and the production of a prototype system. Demonstration/validation of the prototype shall be conducted in a simulated production environment. Evaluation will be based on unit and operational costs, robustness, ease of use/maintenance, human factors/ergonomics, portability, weight, safety, and ability to perform all tasks outlined in the OEM specifications. The contractor shall perform a cost benefit analysis of the prototype design.

PHASE III DUAL USE APPLICATIONS: Phase III will take the prototype demonstrated in a simulated production environment and further develop the system for production use. Upon completion of testing, any redesign effort would be completed to move the prototype into production.

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3. Automated Robot-Based Screw Insertion System. Lara, Bruno; Althoefer, Kaspar; Seneviratne, Lakmal D. King's College London.

4. Additional Q&A from TPOC to clarify requirements for AF Topic AF141-159, uploaded in SITIS 12/10/13.

KEYWORDS: Portable drilling system, fasteners, drill starts, production, drill-fasten, drill and fill, rivets, man-hours, man hours, quality escapes

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AF141-160 TITLE: Abrasion Resistant Coating on Composite Substrates

KEY TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Develop an abrasion resistant coating to help protect sensitive substrates during dry media blast coating- removal operations.

DESCRIPTION: A significant need exists to develop an abrasion resistant coating for composite structures capable of protecting the substrates during media blast coating removal operations. This new coating would function as a protective barrier to the substrate and coatings beneath it. Successful transition of such a technology would have far reaching sustainment benefits to both the USAF and modern commercial aerospace platforms. The new coating must be compatible with currently fielded coating systems and must not impact the function of these existing materials. The technology must be thin (0.5-1.2 mils) and lightweight (compared to COTS coatings currently used of the same thickness) to serve as a dry media resistant barrier to be used on thin skinned composite substrates. The new material must be compatible to new or mechanically stripped composite substrates and the protective coating finish system, i.e. a outer mold line paint stackup. The thin coating should resist any discernible or measurable damage from the following dry media: wheat starch and MIL-P-85891, Type VII. During Phase I, the coating must be demonstrated on at least two representative 12" x 12" composite substrate specimens with a paint stack-up representative of the modern USAF weapon systems. The 12" x 12" specimens will be subject to the following laboratory tests: dry media blast, ASTM D4541 (PATTI), and composite flexibility testing. The coating should be semi-permanent -- it must have a documented removal process (non-media blast) that allows a maintainer to remove the new coating without damaging the coatings/substrate that resides below. The coating must exhibit acceptable adhesion properties to other common coatings and substrates used by the US Air Force. The coating must withstand temperatures, moisture reversion, and UV degradation in a normal operating aerospace environment. It is preferred the technology is compliant with standard coating application equipment so it can be applied by field units in an operational environment.

PHASE I: Demonstrate the new coating to be an abrasion resistant and capable of protecting the substrates during media blast coating removal operations. Demonstrate initial testing to show proposed technology is compatible with and maintains adhesion with current coating stacks before removal. Demonstrate removal of developed coating does not damage coatings/substrate lower in the stack-up.

PHASE II: Demonstrate the coating performance is resistant to conditions seen in operational environment. Perform scale-up activities to establish manufacturing capability to produce coating on a commercial level. Additional demonstrations shall be conducted to show weapon systems potential benefits from the new technology. A return on investment and/or cost benefit analysis will be provided by the contractor to the USAF to assist with transition efforts. Phase III transition plan must be developed.

PHASE III DUAL USE APPLICATIONS: Qualification activities shall be performed. Other activities leading up to a T-2 flight test shall be performed.

REFERENCES:
1. MIL-P-85891A.

2. ASTM D4541 (PATTI), "Standard Test Method for Pull-off Strength of Coatings Using Portable Adhesion Testers".

KEYWORDS: abrasion, coating removal, media blast, OML, maintenance

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AF141-161 TITLE: Remotely Controlled Exhaust Coating Defect Mapping System

KEY TECHNOLOGY AREA(S): Air Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual

use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop a compact, ruggedized remotely controlled exhaust coating defect mapping system.

DESCRIPTION: Assessment of damage in inlets and exhaust cavities is necessary to evaluate aircraft readiness and flight safety. Current procedures rely on human performed inspections consisting of visually locating defects in these confined spaces and manually determining defect types, dimensions, and location for transfer to an assessment system. Manual procedures ensuring 100% inspection within small cavities can be difficult to perform due to maneuverability, are time consuming, and are prone to human error.

The Air Force seeks an automated system capable of robotically traversing serpentine inlets, exhaust and other tight cavities with the ability to inspect 100% of the cavity surface and automatically identify defects such as cracks and missing material. These defects must be accurately referenced to known coordinates within the inlet or exhaust structure. Defect data from this mapping tool must be fed into structural coordinates and photographs must be captured to complete the mapping process. The system must generate a report with the locations, number, size and/or area of defects.

The rover must be highly mobile using tracks or wheels and can be tethered with a cable for data and power. The rover must be capable of automatically traversing a programmed path through the cavity assuring 100% inspection based on the sensing modality. While an optical defect mapping head is envisioned (Line Scan, LIDAR or other optical technology), other sensing systems are acceptable. Modular system architecture with the ability to accommodate a variety of NDI sensing technologies is highly desirable.

The mapping device must be used on fielded air vehicles and cannot damage the surface being traversed. Consideration should be given to collision avoidance and to ensure safe manual removal in the event of system, software, or power failure. The tool should pose no safety hazard to personnel or equipment and must be used in a fueled environment. It shall be capable of being approved for flight line operation. It is expected that this system will be transportable and operable by a single technician. Considerations during the design of any equipment used for this should include: robustness, use in the field, and Class I, Div II certification.

This capability will improve confidence in defect location mapping for transfer to assessment systems. A reduction of maintenance induced damage from maintainers climbing in and out of inlets, exhaust and small cavities for inspections. Additionally, a reduction of maintenance man hours is expected. Inlets and exhaust are inspected before every flight. Detailed inspections on exhaust tailpipes are conducted at the end of every week and at 200 flight hours. These inspections take an hour per cavity plus mapping and reporting time. Maintainers are required to don full protective suits with respirators and locate missing material in extremely confined areas further extending inspections. An automated inspection system will free the maintainer from the demanding task and free them to address other needs.

PHASE I: Develop a compact, rugged defect mapping sensor for inlets, exhaust and small cavities designed to fit onto a carriage. The system must identify cracks 0.010" Wide and map missing material greater than 0.35 sq in. Physical size constraints for the mapping system are 6" H x12" W x13" L. Begin integration onto a mobile, remotely controlled carriage that can traverse at least 14' into a pipe or duct.

PHASE II: Finalize sensor/carriage integration and develop automated movement, damage registration and mapping. System must tolerate engine soot and fluids and recognize damage regardless. Damage mapping in areas of 7"H is required but fidelity must be maintained in larger areas of the cavity. Testing and development on a representative inlet, exhaust or cavity highly recommended, a structure may be provided for demonstration. System must map 100% of the cavity in 60 minutes.

PHASE III DUAL USE APPLICATIONS: This automated inspection tool will benefit military aircraft which require frequenct inspection within small cavities. Commercial aircraft as well as other industrial applications requiring inspection of confined spaces should also benefit from this this technology.

REFERENCES:
1. Roman Louban, “Image Processing of Edge and Surface Defects: Theoretical Basis of Adaptive Algorithms with Numerous Practical Applications,” Springer Series in Materials Science, 1st Ed., ISBN-10: 3642006825, ISBN-13: 978-3642006821, Springer, 2009.

2. M.L. Smith, “Surface Inspection Techniques: Using the Integration of Innovative Machine Vision and Graphical Modeling Techniques,” Engineering Research Series, 1st Ed., Duncan Dowson Ed., ISBN-10: 1860582923, ISBN-13: 978-1860582929, Wiley, 2001.

3. Robert E. Green, B. Boro Djordjevie, and Manfred P. Hentschel, Eds., “Nondestructive Characterization of Materials XI: Proceedings of the 11th International Symposium,” ISBN: 3540401547, Springer-Verlag Berlin and Heidelberg GmbH & Co. K, Berlin, Germany, June 24-28, 2002.

4. Dwight G. Weldon, “Failure Analysis of Paints and Coatings,” Revised Ed., ISBN: 978-0-470-69753-5, Wiley, 2009.

KEYWORDS: Engine, inlet, ehxuast, defect, mapping, coordinates, automated inspection, defect/damage identification, defect/damage registration, nondestructive evaluation (NDE), nondestructive inspection (NDI)

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AF141-162 TITLE: Methods to Enable Rapid Qualification of Additive Manufacturing Processes

KEY TECHNOLOGY AREA(S): Materials / Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop model assisted experimental processes that will rapidly estimate the dimensions of life-limiting defects and their probability of occurrence in additively manufactured and/or repaired components.

DESCRIPTION: Additive Manufacturing (AM) is the process of taking a digital representation of a part or component and directly manufacturing the resulting product using an automated, three-dimensional fabrication technique such as Electron Beam Additive Manufacturing (EBAM) or Direct Metal Laser Sintering (DMLS). Current efforts to use AM for fabrication or repair of hardware require the iteration of empirical Design of Experiments (DOE) to optimize alloy selection and processing parameters. Each DOE yields a large number of physical specimens that are characterized using two-dimensional image analysis. Metallographic data is then analyzed and the process is optimized to yield a required microstructure free from defects such as cracks, un-melted particles, and porosity. Mechanical test specimens are then fabricated and tensile, creep, fatigue, and crack growth properties are determined and used for component design and reliability assessment. Finally, fabricated components are inspected and characterized to ensure their microstructure and properties align with the assumptions used for their design and reliability analysis. This process results in a significant level of effort and cycle time, and a number of iterations are usually required before the process parameters are optimized to design requirements and manufacturability.

Rapid qualification of AM processes will require the development of a methodology that accurately captures the relationship between the key input parameters and location-specific microstructure, as well as the relationship between the microstructure and mechanical properties and component durability. The methodology would integrate process information, non-destructive evaluation (NDE), stress analysis and damage tolerance simulations into the design process. Key input parameters and location specific material microstructure, as well as a relationship between the microstructure and mechanical properties and component durability can be established via DOE – based on analysis for the parameters for which predictive physics-based models are available, or based on specimen testing (and microstructure/ fractography characterization) where such predictive models are not available. The probability of detection of these anomalies can be investigated with a NDE inspection simulation tool (e.g., XRSIM). The likelihood that the predicted array of anomalies will lead to a failure can be determined by a fatigue crack growth simulation. With this approach, the DOE provides initial anomaly information, the stress analysis provides a value for the critical size of an anomaly and the NDE assessment provides a detectability measure. The combination of these tools allows for accept/reject criteria to be determined at the early design stage and enables damage tolerant design philosophies.

It is anticipated that this approach will address the stochastic nature of both process variability (e.g., machine to machine variability) and the geometric complexity typically found in aerospace components and will not be limited to simplified scenarios, such as plates, cylinders, or other simple geometric configurations.

While the above integrated process characterization and modeling effort may add to the initial development cost of AM components, it is anticipated that it will only need to be performed once for a given material system and then form a basis for a probabilistic predictive system that can be relatively easily adjusted for a variety of components of different volumes, geometries and applications. The result is an integrated modeling environment for uncertainty quantification and risk assessment that can be effectively utilized for rapid process optimization and components qualification.

PHASE I: Demonstrate a proof of concept capability that integrates process information, material properties, non-destructive evaluation (NDE) models, and damage tolerance simulations into the design process. With assistance from the TPOC verify relevance and viability of the approach with prospective users. Particular attention should be given in the proposal to the validation protocol of the technique.

PHASE II: Further develop the product from Phase I. Identify and include additional factors for improvement following the Phase I proof of concept. Demonstrate the model assisted characterization method on a generic but representative structural aircraft or turbine engine component. With assistance from the TPOC, demonstrate the capability for at least one relevant fabrication or repair application with at least one prospective end-user. Develop a business model for application of the methodology.

PHASE III DUAL USE APPLICATIONS: Further optimize the methodology based on Phase II results. Develop a toolset that will rapidly estimate the dimensions of life-limiting defects and their probability of occurrence in additively manufactured and/or repaired components. Establish a commercialization plan, and transition technologies.

REFERENCES:
1. Gorelik, M., Peralta, A., Singh, S., “Role of Quantitative NDE Techniques in Probabilistic Design and Life Management of Gas Turbine Components – Part II”, GT2009-60358, Proceedings of IGTI 2009 Conference, Orlando, FL.

2. Bordas, S. P. A., Conley, J. G., Moran, B., Gray, J., Nichols, E., “A simulation-based design paradigm for complex cast components,” Engineering with Computers, Vol. 23, pp. 25-37, (2007).

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4. Achenbach, Jan D., Structural health monitoring – What is the prescription? Mechanics Research Communications 36 (2009) 137–142.

KEYWORDS: additive manufacturing, non-destructive inspection, probability of detection, design of experiments, defect characterization, probabilistic methods, repair

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AF141-163 TITLE: Fabrication of aberration-free gradient index nonlinear optical materials

KEY TECHNOLOGY AREA(S): Materials / Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: To prepare aberration-free gradient index linear and nonlinear optical materials, this SBIR will investigate materials fabrication techniques that enable the control of the real and imaginary linear and nonlinear indices in three dimensions.

DESCRIPTION: The Materials and Manufacturing Directorate of the Air Force Research Laboratory has an interest in developing materials for nonlinear optics applications. Current solid state nonlinear optical materials consist of a monolithic polymer or sol-gel chemistry-based prepared as a slab or step concentration gradient. These materials contain a uniform dispersion of a nonlinear optical material or a semiconductor. The materials respond to laser radiation by various mechanisms including multiphoton absorption, nonlinear refraction, nonlinear absorption and free carrier effects. Examples of these nonlinear optical materials are two-photon-absorbing dyes, polymers like poly(phenylene vinylene), phthalocyanines, platinum acetylides, semiconductor dispersions and quantum dots. Problems with system integration result from linear loss, optical aberrations, laser damage, thermal lensing, formation of scattering centers and excimer formation. Thus, these materials do not perform well in real world optical systems. Improvement of performance and system integration requires invention of materials that have enhanced nonlinear optical response via custom engineered nonlinear light propagation capability in three dimensions. The ability to control the real and imaginary components of the linear and nonlinear refractive index would give the designer additional freedom to achieve system integration. This SBIR will fund research on methods for preparing nonlinear gradient index optical materials with the capability of three-dimensional control of the real and imaginary linear and nonlinear indices of refraction, including the fabrication of axial index gradients, radial index gradients and combination gradients. This capability would make possible optical designs far beyond what can be done today with monolithic elements. Specific applications include design of a multilens system in one element, waveguides, optical interconnects, tailor-made optical elements with designed concentration gradients in three dimensions, management of thermal lensing and optimizing the focal volume. Technologies like multilayer processing, three dimensional laser lithography, ink jet printing and aerosol jet printing make possible fabrication of these new optical elements. Currently it is feasible to fabricate GRIN optics by multilayer processing. It is also feasible to prepare axial concentration step gradients composed of machined polymer slabs. The next step is to prepare a nonlinear optical element with a designed three-dimensional nonlinear index gradient. A fundamental problem with fabricating these materials is inventing techniques to prepare a three-dimensional array of submicron-sized voxels each having a user-specified composition and XYZ coordinate. The performance of a material in an optical system is strongly influenced by the specifications of the optical system. These methods will improve system integration by making possible system-specific optical element design. An example of a cylindrical optical element that could be prepared by this technique would be composed of a mixture of a linear optical polymer with a nonlinear optical polymer. Example specifications are length = 1 mm, diameter = 1 cm, parabolic radial nonlinear index gradient with nonlinear optical susceptibility at the center = 1000x that of silica. Deliverables include optical slabs with designed concentration gradients in three dimensions similar to a Wood lens and an all-in-one optical system composed of linear and nonlinear elements. Final success of this technology would involve design of a nonlinear optical system by beam propagation modeling, fabrication and proof of concept by measurement of the beam profile entering and exiting the system.

PHASE I: Prepare a cylindrical (1 cm diameter x 1 mm thickness) solid state nonlinear GRIN lens with a parabolic radial nonlinear index gradient. The difference in third order susceptibility between the center and edge should be 1,000x that of silica. The lens is a three-dimensional array of sub-micron scale voxels having specific XYZ coordinates and mixtures of a linear and nonlinear optical material. .

PHASE II: The Phase II research program will build on the knowledge obtained in the Phase I program by fabricating gradient optical systems with variation of the real and imaginary refractive index in three dimensions. The research will demonstrate gradients containing nonlinear materials including chromophores, nonlinear polymers, semiconductor quantum dots and two photon absorption materials. Deliverables of the materials will be provided to AFRL for linear and nonlinear optical characterization

PHASE III DUAL USE APPLICATIONS: The Phase III research program will focus on fabrication of optical elements according to a design. The designs include commercial devices like optical interconnects and waveguides. The measured nonlinear optical performance of these elements will be compared to beam propagation modeling data.

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KEYWORDS: gradient, GRIN, nanocomposite, photonics,microlens

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AF141-164 TITLE: Programmable Accelerated Environmental Test System for Aerospace Materials

KEY TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Develop a programmable materials test apparatus that can reliably control simulated environmental conditions.

DESCRIPTION: Compliance with ASIP (Aircraft Structural Integrity Program), specifically the five tasks stated in MIL-STD-1530C, including establishment of a corrosion control program (Task I) and corrosion assessment (Task II), is mandatory for all USAF aircraft weapon system programs. However, there are currently no design trade tools available to the ASIP community to account for the effects of corrosion protection materials and processes, particularly outer mold line organic coatings, in an effective manner analogous to the way fatigue is accounted for using damage tolerance models for crack growth. This goal is made more challenging because increasingly stringent environmental regulations are restricting the materials that can be used on aircraft e.g. hexavalent chromium, while at the same time the service life of some aircraft platforms have been extended far beyond what was intended for the original design. This necessitates consideration of emerging coatings which can have an array of corrosion inhibition mechanisms (e.g., Mg-rich Zn primer). Currently, ASTM B 117 (5% NaCl neutral salt spray at 35ºC) is used as the standard test method for coated aluminum substrates, but is not viable for evaluating the emerging coatings because it often yields an inaccurate or misleading prediction of in-service performance. This is most likely because ASTM B117 does not expose test articles to combinations of environmental factors that lead to degradation of materials in service.

The apparatus to be developed in this program is needed so that new, more accurate accelerated test methods can be created to advance the development of environmentally compliant coatings for corrosion protection by facilitating rapid performance analysis of new materials. The apparatus must be able to apply and control the following conditions: salt spray with ability to alternate between 3 or more electrolyte solutions (NaCl, $CaCO_3$, $NaHCO_3$, etc.) during the same test, temperature (-65ºF to 250ºF), pressure monitoring, relative humidity (up to 100%, variability +/- 5%), and irradiation using an energy spectrum close to that of natural sunlight, with higher than natural spectral irradiance up to 50 W/cm2 in the UVA range (320-400 nm). The apparatus must also be able to apply and control ozone, CO_2, and at least one other interchangable background gas during operation. The ozone concentration range must be 30 ppb minimum up to 30 ppm maximum with variability +/- 5% and ozone monitoring sampling rate of 30 Hz. The CO_2 and other background gases must be regulated, i.e. using mass flow control. The test apparatus must have user-friendly, software-programmable control on/off for all environmental conditions as well as feedback sensors that detect the flow of ozone and automatically shut off and vent the chamber if a valve or seal fails. The applied environmental conditions must be uniform over the area containing the test articles. It is desirable for the system to include the ability to perform cyclic mechanical loading within the test chamber. It is also desirable to be able to monitor material properties of the test articles (e.g., electrochemical processes, elemental composition, optical characterization) in situ during testing using contact and non-contact methods and apply statistical algorithms to collected data to identify significant interactions between applied environmental conditions.

PHASE I: Prove feasibility by design and construction of durable small-scale prototype chamber that can subject a planar area of approximately 1 ft2 to the required environmental conditions and associated tolerances listed in the above description. State plans for inclusion of mechanical loading, material property monitoring, and data analysis. Demonstrate prototype software user interface for control of environment.

PHASE II: Design and construct durable full-scale test chamber capable of subjecting a planar area approximately 6-10 ft2 to the required environmental conditions and associated tolerances listed in the above description. Incorporate cyclic mechanical loading, material property monitoring, and data analysis if applicable. Demonstrate software user interface for controlling all environmental parameters. Deliver prototype system with software to AFRL.

PHASE III DUAL USE APPLICATIONS: Phase III commercialization opportunities abound with aerospace equipment manufacturers, coating formulators, and DoD laboratories. In addition to aerospace, the technology will be directly applicable to facilities and infrastructure protective coating testing and qualification.

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1. Military Handbook (MIL-HDBK)-1530C, Aircraft Structural Integrity Program, Revision C, (USAF, 1 November 2005)

2. ASTM B 117, “Standard Practice for Operating Salt Spray (Fog) Apparatus”

3. GM9540P, “Accelerated Corrosion Test”

4. SAE J1563, “GUIDELINES FOR LABORATORY CYCLIC CORROSION TEST PROCEDURES FOR PAINTED AUTOMOTIVE PARTS”

5. ASTM D 5894, “Standard Practice for Cyclic Salt Fog/UV Exposure of Painted Metal, (Alternating Exposures in a Fog/Dry Cabinet and a UV/Condensation Cabinet)”

KEYWORDS: Accelerated corrosion, hexavalent chromium, ozone, ultraviolet (UV) radiation, organic

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AF141-165 TITLE: Standard Test Method for Prepreg Resin Impregnation Level

KEY TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Develop a standard test method to quantitatively validate prepreg resin impregnation levels with improved fidelity as compared to current practice for better material and process control in the manufacturing environment.

DESCRIPTION: The resin impregnation level is important to downstream processing of the prepreg/tape lay-up material and the resultant composite part quality because of its affect on prepreg lay-down efficiency and air/volatile evacuation prior to and during the composite cure cycle. Partial impregnation is a common practice used to manufacture prepreg materials for the defense industry while full impregnation is used for automated tape materials. The products are used on multiple DoD aircraft platforms to benefit part quality through improved process-ability. Air transport occurs via different mechanism depending on the product form (dry mid-plane of prepreg verses interstitial gap in tow/tape placement). Successful air evacuation is especially vital to new generation, vacuum bag only (atmospheric pressure only) cured systems. Improved process-ability translates to improved repeatability and generally improved mechanical performance. This effort will focus on the development of a standard test method which will measure the level of resin impregnation into a fiber bed during prepregging. Current, state-of-the-art test methodologies correlate water uptake levels with fiber bed free volume in a partially impregnated prepreg material. The accuracy/repeatability of this technique is estimated to be +/-5%. A test method with an accuracy of +/-1% is desired to provide composite part fabricators and end users with better confidence in their raw materials, products, and reduced manufacturing cost of quality by enabling material specifications to incorporate prepreg batch acceptance requirements for impregnation level.

PHASE I: The Phase I effort would include the development of methods to quantify level of impregnation (LOI) along with experimental validation proving feasibility. A down-select to the most promising and industry practical method is desired. Develop a preliminary transition plan including test method specification acceptance.

PHASE II: Phase II would focus on developing and building a prototype measuring device and developing American Standard Test Method (ASTM) or similar test method guideline. The effort would include demonstration of the selected technique for measuring LOI with a +/-1% accuracy for prepreg and automated tape-grade materials at the material or part supplier. Refine transition plan.

PHASE III DUAL USE APPLICATIONS: Phase III would involve commercialization of the product and LOI method. Demonstration that this method is able to quantitatively measure the LOI in prepreg batches for supplier part quality correlation would be desired. Submission to ASTM committee for new standard acceptance is expected.

REFERENCES:
1. Peltonen, P., et al. "The influence of melt impregnation parameters on the degree of impregnation of a polypropylene/glass fibre prepreg." Journal of Thermoplastic Composite Materials 5.4 (1992): 318-343.

2. T. Centea, P. Hubert, Modelling the effect of material properties and process parameters on tow impregnation in out-of-autoclave prepregs, Composites Part A: Applied Science and Manufacturing, Volume 43, Issue 9, September 2012, Pages 1505-1513.

KEYWORDS: composite, prepreg, partial impregnation, standard test method

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AF141-166 TITLE: Aircraft Fastener Smart Wrench

KEY TECHNOLOGY AREA(S): Air Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop a handheld, computer controlled wrench capable of installing commonly used aircraft nuts and collars. The device should be capable of measuring the number of exposed threads and informing the user of improperly installed fasteners.

DESCRIPTION: Aircraft manufacturing involves the installation of thousands of a variety of fasteners critical to the structural integrity and performance of the airframe and has strict quality control requirements. Current Air Force acquisition programs have numerous Critical to Quality (CTQ) features for fastener installation that require careful visual and manual inspection and measurements to ensure compliance with engineering specifications. These aircraft inspection and measurement methods are very labor intensive. Because of the large volume of fasteners involved, many hours are needlessly spent conducting post-installation inspections of aircraft fasteners that are already compliant with fastener installation requirements.

The objective of this effort is to develop an intelligent, hand held smart wrench system capable of installing a variety of structural aircraft nuts and collars and measuring and storing installation inspection/measurement results. Aircraft manufacturers and Air Force systems would benefit from a system capable of real-time manipulation and feedback. The system should be capable of installing commonly used nuts and collars during the assembly process for current manufactured AF aircraft systems. The system should have the ability to swage the Alcoa Eddie Bolt 2 eddie nut shown in the reference section. The system should have the ability to measure post-installation fastener thread protrusion to the nearest 0.0083 inch, to store and deliver data and installation reports compatible with OEM data storage systems, and immediately inform the user of any fastener installation corrective action that is required. The system should be configured to provide a logical user interface and calibration procedures should be straightforward and quickly performed. The prototype should be robust and maintain operability in an environment where the unit could be inadvertently dropped from heights of up to 5 feet with no adverse impact on system capability.

Because the system will be used in a variety of different structural configurations, it will be critical for potential offerors to work closely with an aircraft original equipment manufacturer (OEM) and a working relationship already established with an OEM is preferred.

The overall goal of this SBIR project is to deliver a mature prototype unit to an Air Force approved OEM that provides specified requirements capabilities at an affordable cost of no more than $2500 / unit. The Phase I effort should focus on demonstration of the hand held proof of concept. The Phase II effort should focus on optimizing the Phase I design, developing an acceptable user interface and calibration tools, designing a system that is applicable for use in the necessary structural configurations, hardening the system against inadvertent drops and demonstrating that the system meets TRL-7 and MRL-7 requirements. Periodic technology and manufacturing readiness level assessments should be incorporated into this project.

PHASE I: The focus of Phase I effort is the demonstration of a proof of concept hand held system on actual aircraft fastener parts. Perform initial business case analysis, manufacturing assessment, and transition plan.

PHASE II: Develop prototype unit based on the Phase I development and results. Deliver a prototype and perform initial field testing in coordination with an aircraft OEM. Demonstrate system operability to TRL-7 and MRL-7. Based on test results, identify and perform, if possible, all required iterative modifications. Update the business case analysis and manufacturing/transition plan.

PHASE III DUAL USE APPLICATIONS: Finalize transition to other military and commercial partners.

REFERENCES:

1. Alcoa Eddie Bolt & Nut Brochure
http://www.alcoa.com/fastening_systems/aerospace/en/pdf/eddie_bolt_2_flyer_lr.pdf.

2. Example Pin Protrusion Gauges http://www.deltaintl.com/Hi%20shear/gages/Pin%20Protrusion%20Gages.html.

KEYWORDS: Aircraft Fastener, aircraft wrench, aerospace fastener

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AF141-167 TITLE: Realistic Test Methods for Aircraft Outer Mold Line Treatment Materials

KEY TECHNOLOGY AREA(S): Materials / Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop a repeatable and accurate test fixture, testing methodology, and data collection protocol to assess the durability of outer mold line treatment stack-ups applied to external joints of a high performance fighter and/or bomber aircraft.

DESCRIPTION: Fifth-generation fighters and modern bombers require materials that can withstand joint flexure without cracking, shrinking or thermally expanding over the life of the aircraft. When damaged, current material systems require extensive maintenance man-hours resulting in high rates of aircraft downtime. Although these materials systems must pass 'qualification' testing, the materials continue to fail at high rates indicating insufficient and/or inadequate test protocol. Thus, a novel standardized test producing accurate stress/strain fields and realistic environmental conditions for outer mold line (OML) treatment stack-ups is desired. Focus should be placed on developing a novel, multi-configuration test fixture along with testing methodology that simulates stress concentrations due to geometry, tensile, compression, and shear fatigue mechanisms across aircraft joints that occur around quick access, infrequent, and frequent access panels. The testing methodology should accurately simulate the harsh environmental conditions, stresses, vibration, flexure and fatigue and aircraft's OML joints experience over the life cycle of the aircraft. The proposed protocol must be performed as a laboratory test that can be carried out with either standard or customized laboratory equipment available at a reasonable cost. A single test fixture is preferred, but multiple test fixtures to simulate the aforementioned joint configurations is acceptable. The test fixture should accommodate testing on an individual material as well as a multi-material stack so conditions can be broadened/focused as needed. The test method should also address Coefficient Thermal Expansion (CTE) mismatch and thermal expansion of coating materials in and over the joints. For CTE's evaluation, the substrates utilized should be constructed of conventional aircraft materials (e.g. aluminum, carbon fiber and titanium). Cycling of stresses and thermal loads is desired over a temperature range of -65ºF to 700°F. An accurate in situ determination of disbonds, cracking, delaminations and electrical discontinuities is needed to determine material performance in real time. The generation of materials property data, including hysteresis and error is required. The test method should be as simple as possible while able to be adjusted for a variety of simulated flight environments, profiles, and ground conditions. Utilizing aircraft manufacturers to assist in providing information on current joint geometries, methods and procedures is highly recommended. Researchers should be familiar with current ASTM practices and procedures for aircraft materials (see references).

PHASE I: Demonstrate test fixture(s), test methodology, and data collection protocol on COTS or otherwise available materials under ambient conditions. Identify improvements over current ASTM standards. Specify all COTS/custom equipment and software requirements. Demonstrate the operating envelope, reliability, and reproducibility of the fixtures and methodology. Develop Phase II transition plan.

PHASE II: Demonstration of test fixture(s), test methodology, and data collection protocol on materials stack-ups under variable conditions (temperature, pressure, humidity, vibration, etc.) to simulate operational aircraft environment. Demonstrate the accuracy of the test instrumentation and ability to determine failure mechanism (disbonds, cracking, delaminations, electrical discontinuities, etc.). Develop test bias, reliability and reproducibility information. Refine transition plan.

PHASE III DUAL USE APPLICATIONS: Commercialization of the test fixtures, methodology, and data collection protocol and the establishment of the protocol as standard test methods (ASTM, SAE, etc.).

REFERENCES:

1. ASTM D2240--Standard Test Methods for Rubber Property—Durometer Hardness.

2. ASTM D7028--Standard Test Methods for Glass Transition Temperature of Polymer Matrix Composites by DMA.

3. ASTM D1002--Standard Test Method for Apparent Lap Shear Strength of Single Lap Joint Adhesively Bonded Metal Specimen by Tension Loading.

4. November 19, 2008, Xingcun Colin Tong, Advanced Materials and Design for Electromagnetic Interference Shielding,

5. March 1, 2009, John S. Dick, Rubber Technology 2E: Compounding and Testing for Performance.

KEYWORDS: Adhesive, tape, bond, filler, gap, mechanical, environmental, standard.

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AF141-168 TITLE: Chrome-Free Room Temperature Curing Fuel Tank Coating

KEY TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Develop an alternative non-chromated fuel tank coating that can cure at room temperature and meets the requirements of Society of Automotive Engineers (SAE) AMS-C-27725.

DESCRIPTION: SAE AMS-C-27725 fuel tank coating is a proven technology for inhibiting corrosion and microbial growth in aircraft structures that are in contact with jet fuel. Hexavalent chromium, an ingredient in SAE AMS-C-27725 materials is an Environmental Protection Agency (EPA) toxic material and a significant occupational health concern with exposure limitations proposed by the Occupational Safety and Health Administration (OSHA). In addition, the elevated heat curing of some currently approved fuel tank coatings increases manufacturing costs and is not feasible for field level repair. The use of currently approved chromated and/or heat cured fuel tank coatings is financially and logistically cumbersome, affecting the aircraft throughout the entire lifecycle.

The Air Force is seeking a new room temperature curable coating that is non-chromated, meets the current fuel tank coating performance requirements, and is compatible with other aircraft system materials. The application of the coating should not interfere with logistical and operational requirements of the manufacturer or potential Depot level users. The material should allow application by either high-volume low-pressure spray equipment or a brush. The candidate coatings must demonstrate compatibility with SAE-AMS-3277 and SAE-AMS-3281 fuel tank sealants when compared to the baseline fuel tank coating. The candidate coating must also demonstrate adhesion to graphite/epoxy composites and be able to conform to geometries consistent with fastener rows. Specific material properties pertaining to corrosion protection, adhesion, microbial growth inhibition, and fluid resistance are listed in the reference section of this solicitation. In addition, DiEGME resistance is preferred, but not required.

Collaboration with end users such as prime contractors is highly encouraged.

PHASE I: Identify and develop innovative material(s) to meet fuel tank coating requirements and demonstrate the feasibility of meeting the requirements of AMS-C-27725 and the requirements listed above. Develop initial transition plan and business case analysis.

PHASE II: Develop, test, and demonstrate the characteristics of the proposed materials to meet or exceed the requirements of AMS-C-27725. Validate material compatibility with the JSF fuel tank system. Update transition plan and business case analysis.

PHASE III DUAL USE APPLICATIONS: Transition to the Fleet via specification modifications and revisions to aircraft weapon system technical manuals. Resolve any logistical constraints that may negatively affect program schedules.

REFERENCES:
1. SAE AMS-C-27725, Coatings, Corrosion Preventive, Polyurethane for Use to 250° F (121° C).

2. SAE AMS-3277, Sealing Compound, Polythioether Rubber Fuel Resistant, Fast Curing Intermittent Use to 360 o F (182 o C).

3. SAE AMS-3281, Sealing Compound, Polysulfide Synthetic Rubber for Integral Fuel Tank and Fuel Cell Cavities, Low Density (1.20 to 1.35 specific gravity, for Intermittent Use to 360 o F (182 o C).

4. OSHA Request for Information, Occupational Exposure to Hexavalent Chromium (CrVI). Federal Register, Vol. 67, No. 163, 22 August 02.

KEYWORDS: Chrome; Heat-Cure; Room Temperature; Fuel Tank; Coatings; Materials

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AF141-169 TITLE: Automated Surface Microstructure Nondestructive Evaluation (NDE) Process for Aerospace Materials

KEY TECHNOLOGY AREA(S): Materials / Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop and demonstrate an automated technique to nondestructively measure and quantify location specific grain sizes in metallic aerospace materials.

DESCRIPTION: The move toward lighter weight, higher performance components for Air Force applications is driving designers toward the use of tailored microstructures to provide the necessary location-specific properties for materials like nickel and titanium. An example is the dual microstructure engine disk, which contains a transition from fine grains at the bore to coarse grains at the rim. Similar desired properties exist within other structural applications as well, including airframes. Critical to fielding such components is the ability to nondestructively inspect and evaluate the microstructure.

AFRL Materials and Manufacturing Directorate is interested in the development of a nondestructive evaluation system that can detect AND characterize this tailored surface grain size distribution in aerospace nickel and titanium alloys. For example, due to location-specific failure mechanisms in nickel turbine engine disks, fatigue at the bore and creep at the rim, engine manufacturers have developed heat treatment methods to tailor grain size, 5μm-8μm at the bore and 44μm-70μm at the rim1,2. Failure may also initiate from the so-called “as large as” (ALA) surface grains in the material so it is critical to know the location and size of these type anomalies. In titanium alloys, clusters of similarly oriented primary alpha grains, called microtextured regions, may span length scales of several millimeters. Crack extension occurs easily in these regions due to the lack of high angle grain boundaries leading to reductions in fatigue life3. Because these microstructural anomalies (large grains, microtextured regions) may occur at any arbitrary location on the surface of a component, inspection approaches will need to reliably and repeatably measure and record spatially resolved surface grain size and morphology. Current inspection techniques, including eddy current and fluoro-penetrant, can be limited by geometry size and complexity and do not provide the detailed quantitative picture of surface morphology required to assess location specific grain sizes, most notably in the grain size transition regions. Without an automated solution, manual data collection to characterize the surface becomes extremely costly and time consuming. Given the potential for large quantities of production inspections, successful solutions must provide high level quantitative imagery, including spatially resolved grain orientation maps, and be cost and cycle time competitive with existing inspection techniques.

For successful implementation of this new capability, the offeror’s proposed detection and characterization technique is required to be: noncontact (i.e. probes will not directly touch the part being assessed); nondestructive; automated with minimal manual intervention and reduced setup; integrate-able with existing/preferred fixturing and tooling; compliant with existing industry inspection system requirements; and, able to record and store data clearly indexed to the workpiece. In its final implementation state, output from this inspection system must integrate with existing data systems used for statistical process control analysis.

The system should be capable of mapping the microstructure to a minimum resolution of = 20 µm and a desired resolution of = 7 µm at a rate in excess of 2,000 points per second on material with a maximum surface roughness of 120 µ-inch RMS. The prototype system should be able to scan flat, convex and concave surfaces and cover a part volume with dimensions 36” x 36” x 18”. Scalability to encompass larger volumes is desired but not required.

Successful approaches should stress not only potential scanning technologies but equally, the data interpretation algorithms/methods development necessary to provide the desired information regarding grain size and orientation distribution.

PHASE I: Develop and demonstrate the feasibility of the system concept described above. Stress data analysis to characterize the microstructure. System design should include analysis methods, software, hardware, and external interface components including assembly tooling requirements and assessment of high-risk technologies required for characterization of complex geometries at the desired resolution.

PHASE II: Develop, integrate and demonstrate the critical components of the proposed system developed in Phase I, stressing system performance. Demonstration should include a representative inspection piece, environment and set-up of the final product. Demonstration should provide defined approaches to address complex geometry, surface roughness variations, surface treatment variations, and assess the effects of possible coatings. Develop to MRL 5-6 maturity, with systems design & implementation plans.

PHASE III DUAL USE APPLICATIONS: Automated NDE for tailored microstructural materials has future applications for military aircraft engines and structures. Once proven in the military, the proposed technology will have similar commercial applications, both in commercial engines and in advanced structures.

REFERENCES:
1. Tab M. Heffernan “Spin Testing of Superalloy Disks with Dual Grain Structure”, NASA/CR - 2006-214338, EDR–90712, May 2006.

2. T. P. Gabb et al. “Fatigue resistance of the Grain size Transition Zone in a dual Microstructure Superalloy Disk,” NASA/TM-2010-216369.

3. A.L. Pilchak and J.C. Williams, “Observations of Facet Formation in Near-a Titanium and Comments on the Role of Hydrogen,” Metall. Mater. Trans. A, 42A, 2011, pp. 1000-1027.

4. R Smith, S Sharples, W Li , M Clark and M Somekh, “Orientation imaging using spatially resolved acoustic spectroscopy,“Journal of Physics: Conference Series 353 (2012).

5. Steve D. Sharples, Matt Clark, Mike G. Somekh, Elizabeth E. Sackett, Lionel Germain, Martin A. Bache, “Rapid grain orientation imaging using spatially resolved acoustic spectroscopy,” Proceedings of the International Congress on Ultrasonics, Vienna, April 9-13, 2007, Paper ID 1620.

KEYWORDS: tailored microstructure, NDE, hybrid disk, surface morphology, grain orientation, automation, analysis, non-contact

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AF141-170 TITLE: Efficient shaping or reshaping of complex 3D parts using engineered residual stress

KEY TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Develop a computational design tool for defining a surface treatment process to produce a desired shape change in a complex, 3-dimensional part and to validate this model in a representative environment.

DESCRIPTION: Aircraft The fabrication of integral components is a machining-intensive process that employs non-conventional machining at high material removal rates. One method is high speed milling (HSM), which combines high spindle speeds with high feed rates to produce a high material removal rate. At the present time, one of the biggest limitations of HSM of integral structures is distortion. Distortion results from changes in the residual stress state within the machined component. The removal of material originally containing residual stresses causes the residual stresses to re-distribute elsewhere within the component. In addition, the machining process itself induces additional residual stress.

Excessive distortion is a significant concern for aerospace OEMs. Distortion can lead to the introduction of excessive fit-up stresses during assembly, can result in improper joints/connections, and can result in parts being scrapped. In certain instances, machine shops are allowed to use mechanical means (e.g., plastic bending over a fixture) to rectify some of the distortion. This can be effective, but is limited to use on simple geometry and this approach is lacking in quality and traceability. An improved process for correcting distortion (i.e., reshaping back within drawing tolerance) in complex aerospace parts might result in significant cost savings to the aerospace industry.

It is well established that compressive residual stresses provide improved fatigue performance and damage tolerance enhancement. To take advantage of this concept, many surface treatment processes have been developed over the past 60+ years that are capable of imparting compressive residual stress into the surface layer of a component. The surface treatment processes vary in the amount of residual compressive stress they impart (magnitude and depth) as well as many other factors such as: cost, applicability to specific geometric features, and traceability/quality control.

When surface treatments are applied, the induced plastic deformation (which is the driver for compressive residual stress) also causes distortion. In most cases this distortion is an undesirable consequence that is managed by keeping the processed region small or by having a very stiff part. In certain cases (e.g., shot peen forming, which is used to create curved thin panels for aircraft wings) the distortion itself is the motivation for the use of the surface treatment. The use of surface treatments for shaping of parts is currently limited to pretty simple configurations due, in-part, to the difficulty of achieving a desired complex shape without a computational model of the process.

Predictive software tools, which are currently configured to solve the forward problem (solve for distortion and residual stress based on a defined surface treatment process/area), could be adapted to solve the reverse distortion problem (solve for the surface treatment process/area required to produce a desired shape change). When properly developed, this would provide an effective tool for the use of engineered residual stress for shaping complex 3D parts.

The objectives of this program would be to develop a computational design tool for defining a surface treatment process to produce a desired shape change in a complex, 3-dimensional part and to validate this model in a representative environment.

PHASE I: The focus of Phase I effort is the demonstration of a proof of concept and development of the software tools that will be used to compute the surface treatment needed to reshape the part to the desired dimensions. A simulation of the developed software tools is desired in Phase I.

PHASE II: Develop prototype system based on the Phase I development. Integrate 3-D scanning techniques that can used on the part to be reshaped, focusing on critical part interfaces. Use scan data to determine required deformations. A total system demonstration is desired that will reshape a part using these parameters. Optimization and validation of the system shall be demonstrated to be effective in an operational environment (TRL/MRL 7).

PHASE III DUAL USE APPLICATIONS: Integrate into a production and/or sustainment environment.

REFERENCES:
1. Publication number US6410884 B1 Contour forming of metals by laser peening.

2. http://ceramics.org/ceramic-tech-today/manufacturing/removing-distortion-from-thin-ceramics-with-shot-peening?wpmp_tp=0&wpmp_switcher=mobile Removing Distortion from thin ceramics with shot peening American Ceramic Society Newsletter, Published on April 2nd, 2012 | Edited by: Eileen De Guire.

3. http://www.shotpeener.com/library/pdf/2011063.pdf The Method Of Corrective Shot Peening : How To Correct The Distortion On The Machined Parts, Sutarno and Maris Munthe, Indonesian Aerospace Industry (IAe) Jl. Pajajaran 154 Bandung 40174 Indonesia.

KEYWORDS: Aerospace, shaping, reshaping, complex 3D parts, residual stress

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AF141-172 TITLE: Reliable and Large-Scale Processing of Organic Field Effect Transistors for Biosensing Applications

KEY TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Develop techniques and processes for scale-up and production of high performance organic field effect transistors that are suitable for biofunctionalization and can be investigated for biosensing applications.

DESCRIPTION: Biological sensors are analytical devices that incorporate a biological sensing element that binds to a desired target. The sensitivity and selectivity of biological sensing elements in conjunction with field effect transistors provide a means by which to transduce a binding event using a label-free method into an electrical output. Biosensing using organic field effect transistors (OFET) based on soft matter materials is of interest for a variety of applications in chem-bio detection, environmental monitoring, human performance monitoring and in future platforms as an extension of the human skin for enabling man-machine interfaces. OFETs are ideal due to its low-cost, low-power and operation in aqueous environments.

The goal of this topic is to develop a scalable processing of OFETs with reliable and reproducible performance, with design/manufacturing considerations to provide complete device modules. The OFET must be stable in aqueous environments such as serum or sweat, and be multi-use. The OFETs must be amenable to biofunctionalization for the detection of peptides, protein or metabolites in aqueous medium like sweat, saliva or serum. The device must function in flow-through modules to allow for frequent sampling. Approaches compatible with ligands such as antibodies, peptides and aptamers as the biological sensing elements functionalized onto the semi-conducting material are highly encouraged. The OFET platform must be benchmarked with other state of the art technologies such as CNT-FETs, ELISAs or other (bio)chemical approaches.

PHASE I: Develop OFETs functionalized with peptides, aptamers or antibodies. Demonstrate stable and reproducible signal in response to analyte. Demonstrate device-to-device reproducibility with a dynamic detection range, fast response times, stable operation in aqueous conditions (buffer, sweat, or serum). Develop technical roadmap to fabricate devices on a large-scale.

PHASE II: Scale-up and optimize OFET fabrication process of devices in sufficiently large quantity for desired application demonstrations, while maintaining cost effectiveness for potential implementation. Fabricated prototype devices with biosensing functionalities must demonstrate <10% variance in performance and stable operation for > 10,000 measurements cycles.

PHASE III DUAL USE APPLICATIONS: Military Application: Advance sensors for chem-bio, human performance monitoring and man-machine interfaces. Commercial Application: Sensors for healthcare, environmental monitoring. Sensor modules can also find use with law enforcement and first responders.

REFERENCES:
1. Hammock M. L. et al., (2013). Investigation of Protein Detection Parameters Using Nanofunctionalized Organic Field-Effect Transistors ACS Nano 7, 3970-3980.

2. Roberts M. E. et al. (2008) Water-stable organic transistors and their application in chemical and biological sensors PNAS 105, 12134-39.

3. Kwon O. S. et al. (2012) Flexible FET-Type VEGF Aptasensor Based on Nitrogen-Doped Graphene Converted from Conducting Polymer ACS Nano 6, 1486-1496.

KEYWORDS: Transistors, OFETs, Biosensors, Human Performance, Flexible Devices

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AF141-173 TITLE: High Index of Refraction Materials for Printed Applications

KEY TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Develop ink materials which can be reliably used to create low-loss, high refractive index optical components via techniques compatible with roll-2-roll (R2R) related technologies.

DESCRIPTION: The emerging technologies of print/direct write hold promise to revolutionize the way devices and packages are produced, and have many advantages over current manufacturing methods. Traits including low-cost, ease of design and customization, and flat production costs are just a few of the advantages direct write technologies bring to the table [1]. While the majority of current material development for direct write technologies is focused on developing additive techniques for the production of mechanical / structural parts, there is substantial interest in utilizing these concepts for the production of functional components for electronic and photonic devices as well (a.k.a. opto-electronic devices). This approach has already produced some notable successes, such as in display and solar cell technology, where print technology has greatly simplified production processes, or allowed the use of materials that have not been traditionally used [2, 3]. To date, development efforts for direct write inks have been limited to metal colloidal inks for conductive material fabrication towards electronic and RF operation. These electronic ink materials are available commercially off the shelf and investment strategies exist to enhance the electronic ink material variety and robustness. As data routing and processing demands continue to increase, on-chip photonic components are becoming ever-more critical to integrate with the electronic components to create more versatile opto-electronic devices to adequately meet required data handling rates and other critical metrics such as heat output and robustness [4]. However, there is an unmistakable deficiency of available proven ink materials to fabricate the necessary photonic components in opto-electronic devices.

The objective of this topic is to develop ink materials and associated processes which can be reliably used to create low-loss, high refractive index optical components such as printed high performance waveguides, modulators, infrared sources and detectors via techniques compatible with roll-2-roll related technologies. The components written with the ink materials must ultimately have comparable relevant metrics to lithographically fabricated components. While specific metrics will be unique to the particular components fabricated, examples of such metrics with respective approximate values for optical components are optical loss (< 0.5 dB/cm), high index (n > 1.5), tunable index (0.02 < ?n < 0.50), feature resolutions (< 200 nm), surface roughness (< 10nm), and degree of crystallinity (semi-crystalline or greater). Possible ink materials that could fill this gap are inks made from nanoparticles of traditional high-index materials, such as Si, Ge, GaAs, ZnS, $BaTiO_3$, $LiNbO_3$ as well as high index polymers. The deposited ink should require minimal post-processing after it is printed to attain its desired properties, and characterization of the ink would allow for a known surface energy, thereby ensuring that the ink and substrate can be tailored to each other for optimal printed performance.

PHASE I: Develop, synthesize, and demonstrate an ink that enables roll-2-roll printing of high index optical components via commonly utilized print/direct write manufacturing techniques (e.g. inkjet, gravure, transfer, embossing, aerosol jet printing). A simple printed test pattern of the material shall be demonstrated and characterized.

PHASE II: Fabricate an optical component from the ink developed in Phase I. Characterization of the component will be made and appropriate metrics will be compared to analogous components deposited by standard techniques. Ink processing, post-processing, and additives will be tailored to render it compatible with materials commonly associated with flex hybrid concepts, e.g. flex substrates, electrical components. Development will begin on scaling up ink fabrication.

PHASE III DUAL USE APPLICATIONS: Possible applications of the developed inks and printed optical components include but are not limited to flexible electro-optic sensors, conformal antennas, energy harvesting devices, and other electro-optic applications. Steps will be taken to commercialize the developed ink(s).

REFERENCES:
1. http://namii.org/.

2. J. Vaillancourt, et al., "All ink-jet-printed carbon nanotube thin-film transistor on a polyimide substrate with an ultrahigh operating frequency of over 5 GHz," Applied Physics Letters, vol. 93, pp. 243301-3, 2008.

3. M. Hedges, "3D Large Area Printed & Organic Electronics via the Aerosol Jet Process," presented at the LOPE-C, 2010.

4. N. Lindenmann, et al., "Photonic wire bonding: a novel concept for chip-scale interconnects", Optics Express, vol. 20, no. 16, pp. 17667, 2012.

KEYWORDS: Inkjet, Aerosol jet, printed optics, high-index, infrared, photonics, roll-2-roll

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AF141-174 TITLE: Computational Tools to Virtually Explore Material's Opportunity Space from the Designer's Workstation

KEY TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Integrate materials science and engineering (process, microstructure, and performance) model predictions/simulations into industry standard design practice via modification of and/or integration with commercial state of the art finite element codes.

DESCRIPTION: The SBIR will identify options and present solutions to enable moving today's structural design paradigm from the use of materials as fixed design inputs (i.e. lookup table property values tied to existing fixed processes) to actual active variables in structural design (Ref 1). The ultimate vision would be the evolution of design practice to the point that structural design would drive materials requirements and real-time exploration of materials/compositions/processing options that can and will be adjusted in the same vein as the current design community's alteration of shape to accommodate loads requirements (Ref2). The objective of this SBIR is to identify potential solutions and ultimately develop methodologies and software approaches to integrate materials science and engineering (process, microstructure, and performance) model predictions/simulations into commercial finite element design codes as replacements for today's "lookup table" datasets. The SBIR will explore means of integrating with and potential required modifications of existing commercially available finite element analysis software such as ABAQUS, ANSYS, NX Nastran etc. (which are the current standard design tools of the aerospace structural community) in the accomplishment of this task (Ref 3). As necessary, the SBIR will identify and develop (as necessary) high-level methods and computational algorithms to optimize/explore option space by independently triggering materials science models/simulations to explore feasibility space and identify potential solutions from/through the commercial finite element codes. Furthermore, the SBIR must address the Air Force's need to utilize location specific properties that will require process and/or material variation within a single component. The SBIR will develop solutions in a pervasive manner that accommodates most classes of structural materials including, metals, organic matrix composites, ceramics, and ceramic matrix composites.

PHASE I: Research, develop and evaluate concepts for the digital integration of materials and processes beyond fixed lookup tables (i.e. incorporating modeling and simulation) into state of the art finite element structural design tools. Downselect to one approach based upon feedback from government, industry, and market analysis and develop a research and development implementation strategy.

PHASE II: Develop software/modeling and application methodology products to allow designer “reachback” to actively, virtually, explore materials and processes opportunity space through his/her design tools. To validate success, exploration of the methodology’s ability to meet the Air Force's need to utilize location specific properties as well as applicability to accommodate several classes of structural materials will be demonstrated.

PHASE III DUAL USE APPLICATIONS: Software that integrates the materials and processing computational options space with the designer’s design tools is of inherent value not only to the aerospace community (both military and commercial), but other industries requiring structural design (e.g. heavy equipment, auto, power, etc.).

REFERENCES:
1. National Research Council of the National Academies, Integrated Computational Materials Engineering, A Transformational Discipline for Improved Competitiveness and National Security, The National Academies Press, 2008, pp 92-100.

2. National Research Council of the National Academies, Materials Research to Meet 21st Century Defense Needs, The National Academies Press, June 2003, pp 37-40.

3. McDowell, D.L., “Simulation-Assisted Materials Design for the Concurrent Design of Materials and Products,” JOM, Vol. 59, No. 9, 2007, pp. 21-25.

KEYWORDS: Integration, Integrated, integrated computational materials science, Multi-scale, materials, structural design, design with materials, software, finite element analysis

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AF141-175 TITLE: Advanced sub-scale component high temperature multi-axial test capability

KEY TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: The objective is to develop an advanced test capability for measuring sub-scale components under aerospace propulsion service environments to include high temperature and loading conditions within a sub-scale spin test environment.

DESCRIPTION: The SBIR will develop an advanced test capability for measuring sub-scale components under propulsion service environments to include high temperature and loading conditions within a sub-scale spin test environment. The capability will capture the complete test environment, including ability to operate under controlled atmospheric conditions to simulate engine operation.

This information is crucial for determining load conditions and mechanical response under actual propulsion environments and will provide critical information for modeling material and component response and for evaluating coating and advanced material behavior prior to full component testing. In addition, the research will develop computational models of material performance for design integration, including the modeling of mechanical properties currently unavailable due to power constraints associated with full spin tests at atmospheric conditions.

Specifically, the test capability will measure multi-axial stress states in metallic components subjected to sub-scale spin tests. Advanced finite element models will be used to verify and validate test results, and to model the mechanical response of test samples. The models will incorporate relevant microstructural features as warranted to provide for optimization of site specific features and graded structures. The resulting information will be provide integrated computational materials science engineering data for component design engineers to utilize in component design optimizations.

In addition, specific loading conditions and environmental stresses associated with test profiles will be translated into optimized sample material features, as validated by the finite element models and test performance.

PHASE I: The phase will baseline the state of the art in multi-axial testing as it applies to capturing material states within spin test environments and actual propulsion systems during operation, and provide test requirements/conditions to mimic proposed engine cycles. It will propose the sub-scale test system and sample configurations along with analytic models required for validation and verification.

PHASE II: The phase will complete the develop and testing of the sub-scale test capability, complete development of the finite element models, verify and validate the microstructure / property models, and provide the integration toolsets for design optimization. In addition, the phase will develop the connections between optimized material features and relevant engine performance that captures current propulsion system operation, including temperatures and atmospheric conditions.

PHASE III DUAL USE APPLICATIONS: Phase III will invovle optimization of the test systems, development of testing protocols, modeling of stress states within components and adaption of the system for propulsion disks.

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1. R Boyer, EW Collings, Material Properties Handbook, Titanium Alloys, ASM International (1994).

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KEYWORDS: Propulsion, spin-testing, multi-axial-strain

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AF141-177   TITLE: Near Real-Time Processing Techniques for Generation of Integrated Data Products

KEY TECHNOLOGY AREA(S): Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual

use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Research and develop real-time processing techniques integrating 3-D ladar and electro-optic for enhanced search and identification. Generate actionable data product for warfighter applications.

DESCRIPTION: The Air Force needs improved real-time imaging and data integration capabilities for targeting pods and turreted systems such as the Northrop Grumman AN/AAQ-28 Litening targeting pod. Multispectral imaging provides the means to find and characterize sensed objects within a relatively large search area. 3-D ladar can provide means for precision geolocation, target background segmentation, and aid in target identification. Integrating 3-D ladar data with multispectral and other sensing phenomenologies currently requires substantial processing capabilities and time. Bandwidth limitations of communications links such as Common Data Link (CDL) further limit the ability to transfer large datasets in real time. A new capability is needed to provide real-time ladar and electro-optical signal processing, data integration, geo-referencing, and product development for both remote and urban datasets.

Geiger Ladar systems collect large data sets which require substantial processing time and are typically processed post flight. Current systems can require processing to collection ratios of two to five to provide a viable data product, which is typically performed post flight. Linear mode systems can experience similar delays when imaging areas larger than the sensor field of view. Overlay of passive imagery or electro-optic imagery requires additional processing and system knowledge to account for image distortions. Registration of ladar data as collected from a moving platform requires sufficient knowledge of system and environmental parameters to perform real-time processing. System characterization should be known in order to sufficiently compensate for system timing issues, boresight errors of laser with receiver, quantify detector noise, and determine detector saturation. Processing methods should correct for image striations, intensity based corrections, feature based transformations, and registration anomalies, including multiple surface returns.

This solicitation seeks the development and demonstration of algorithms and processing methods needed to achieve real-time presentation of collected flight data and information gained by multimodal analysis. The processing methods should be capable of registering data from a small format Geiger or linear mode arrays and rendering in a wide area map. These methods should compensate for the fast quenching of photon-counting detectors, as well as linear-mode detectors. The effort will lead to real-time generation of 3-D information for user display as applicable to warfighter applications. Integration of electro-optic, navigation information, and visible imagery as collected from an aerial fixed wing platform at operational altitudes. Generation of lower density products for transmission is also needed. This effort will improve the processing to collection ratio toward unity and improve near real time (< 1 second response time) generation of data products to a user. Design approaches should investigate pod-hosted processing capabilities implemented as an open architecture solution, providing a data product in a low format to the aircraft display.

The processing methods should follow the product level construct as defined by NGA, where L-1 through L-5 are implemented in an enterprise interoperable manner. The desired performance will address tactical and nontraditional ISR, where tactical applications would provide a near video rate data product representing a target-sized frame to the user. Nontraditional ISR applications would provide imaging of modest sized areas commensurate with the area rate collected by the sensor. The effort will also demonstrate algorithms for georegistration based on typical targeting pod capabilities.

Military applications include manned or unmanned targeting and mapping missions, while commercial applications include mapping for urban development, agriculture, scientific research, or security.

PHASE I: Develop proof of concepts and design approaches meeting the described performance and functionality for generation of data products from a small array photon-counting and/or linear-mode system for warfighter applications as implemented in a targeting pod. Develop a program plan for system designs and integration through Phase III. Develop a commercialization plan.

PHASE II: Develop architecture, algorithms, and processing techniques for processing of data from a laser radar imaging system. Develop a data product demonstrating the near real-time processing capability in a laboratory environment using simulated data. Show expected performance of an embedded system as implemented in a targeting pod using hardware, such as a VPX protocol. Simulated sensor data may be provided.

PHASE III DUAL USE APPLICATIONS: Develop the processing capability for a specified ladar sensor and perform a ground test with hardware installed in a targeting pod demonstrating the imaging and processing capability.

REFERENCES:
1. Daniel G. Fouche, “Detection and False-Alarm Probabilities for Laser Radars that use Geiger-Mode Detectors,” Applied Optics, Vol. 42 No. 27, September 2003.

2. Community Sensor Model Working Group, “Light Detection and Ranging (LIDAR) Sensor Model Supporting Precise Geopositioning, Version 1.1,” NGA.SIG.0004_1.1, August 2011.

3. R. Craig, Dr. I. Gravseth, Cr. R. Earhart, et al., “Processing 3D Flash LADAR Point Clouds in Real Time for Flight Applications”, Proc. of SPIE, April 2007.

4. Richard Cannata, William Clifton, Steven Blask, Richard Marino, “Obscuration Measurements of Tree Canopy Structure Using a 3D Imaging Ladar System,” Proc. of SPIE 5412, September 2004.

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KEYWORDS: lidar target detection, lidar target tracking, lidar, ladar, laser radar data processing, image

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AF141-178 TITLE: Topographic/HSI Active Transceiver (TOPHAT)

KEY TECHNOLOGY AREA(S): Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: To develop a NIR-SWIR scanning active hyperspectral imaging (HSI) transceiver system with the required processing technology for day/night operations. Current airborne hyperspectral surveillance NIR-SWIR systems are limited to daytime operations.

DESCRIPTION: Near-infrared-short-wave-infrared (NIR-SWIR) HSI systems measure reflected solar illumination and are limited to daytime use. Broadband laser illuminators (BLIs), combined with a NIR-SWIR HSI scanning receiver would support day and night operations. A BLI allows innovative processing and illumination modes (e.g., laser only, or simultaneous or sequential laser and solar). Existing HSI systems are used for near-nadir wide-area search, but a BLI may allow for long-range cued modes. This topic will develop an HSI active transceiver and processing/calibration methods to demonstrate day/night hyperspectral imaging in the NIR-SWIR at moderate ranges to support future work towards a full-scale, long-range system.

Along with the challenges of developing a high-powered BLI, there are challenges associated with developing an appropriate HSI receiver, scanner, and processing methodology, which is the primary focus of this topic. BLIs produce a spot size that varies with wavelength; additionally, atmospheric turbulence will impact the ground irradiance distribution. The HSI receiver and processing must be able to effectively calibrate/compensate for these artifacts. The transceiver design must be able to coordinate scanning of the receiver and laser. The transceiver shall provide ground coverage rates of 4 to 5k m2/sec (Phase II) (O); and 65 to 75k m2/sec in Phase III (T). System operation should support existing intelligence, surveillance and reconnaissance (ISR) concepts of operation (CONOPs). New CONOPs that may be enabled by an active HSI system should be considered.

The system requires spectral response from 1.4 to 1.8 microns (T) to 1.0 to 2.5 microns (exclusive of absorption bands) (O), a nominal spectral resolution of 10nm (T), and a Ground Sample Distance of 1m (T), 0.5m (O). Laser irradiance normal to the line-of-sight shall approximate the irradiance produced by the sun at zenith in the receiver band(s) (T). The system signal-to-noise ratio (SNR) must be sufficient to differentiate between similar spectral targets (T), provide an average SNR of 30 (O) for man-made targets. The system shall provide a day/passive mode of operation (T). Scan accuracy and repeatability shall allow for georegistration of the data cube with topographic data (georegistration need not be demonstrated in a Phase II effort). The design shall provide for a moderate-range and power transceiver for data collection and algorithm development in Phase II and be expandable to a long-range, militarily useful system in a Phase III effort. The system shall meet the thresholds or objectives at a nominal 2 km slant range and operate from 1 to 3 km slant range with degraded performance (T). The 2 km imaging geometry will support tower-to-ground (100-300 foot sensor elevation above ground level) (T), and mountaintop-to-ground (1000-2000 foot sensor elevation above ground level) (O) scenarios. The system shall operate in a moderately turbulent atmospheric environment (Cn2 = 10e-14 (O)). Atmospheric path transmission may be predicted for the Phase II and III efforts using the US Standard atmosphere, mid-latitude summer, 23 km visibility modeling parameters (T). Operation at 5 km visibility is desired (O).

Notional goals for a Phase III system include a 15,000 to 30,000 foot near-nadir operation (wide-area search) up to 50,000 to 60,000 foot slant-path narrow-area cued modes, selectable/multiple GSDs, a two-band (within the 1.0 to 2.5 micron NIR/SWIR band), 1000 watts/micron illuminator, operation in 2x Hufnagel-Valley model turbulence, and size, weight, and power (SWAP) consistent with a 24- to 28-inch airborne turret or pod.

PHASE I: This phase will develop architectures for the Phase II/III transceiver(s) comprising a BLI, receiver, scanning system, optics, and processing. The offerer shall optimize the source, scanner, and receiver to provide useful and programmable ground coverage. The effects of backscatter and turbulence shall be considered.

PHASE II: Design, fabricate, integrate and test a 2 km-range prototype. Provide an Interface Control Document (ICD) and source data to support a laser safety permit. Incorporate ANSI and OSHA requirements for laser sources. The Phase II prototype hardware will be robust enough to undergo laboratory and tower testing. A complete transceiver is deliverable under this phase. Final testing will be conducted at a government facility supporting the required evaluation of performance.

PHASE III DUAL USE APPLICATIONS: A Phase III transceiver would provide long-range, day/night identification of military-specific materials. A civilian transceiver system could support day/night disaster recovery, search-and-rescue, land-use and natural resource surveys when coupled with a wide-area coverage instrument.

REFERENCES:

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2. “Spectral LADAR: Active Range-resolved Three-dimensional Imaging Spectroscopy,” Powers and Davis, Applied Optics, Vol. 51, No. 10, April 2012.

3. “Modeling, Development, and Testing of a Shortwave Infrared Laser Source for Use in Active Hyperspectral Imaging,” J. Meola et al., Proc. SPIE, Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery XIX, Vol. 8743, 2013.

4. "Power Scalable > 25 W Supercontinuum Laser from 2 to 2.5 um with Near-diffraction-limited Beam and Low Output Variability," Vinay Alexander et al., Optics Letters, Vol. 38, No. 13, July 1, 2013.

KEYWORDS: active imaging, LADAR, Hyperspectral Imaging, laser imaging, ladar

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AF141-179 TITLE: Imaging Techniques for Passive Atmospheric Turbulence Compensation

KEY TECHNOLOGY AREA(S): Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Support A2/AD sensing needs by developing technologies to overcome range limitations caused by atmospheric turbulence on current airborne imaging sensors. Based on new technology combining passive adaptive optics with computational techniques.

DESCRIPTION: Air Force high and medium altitude intelligence surveillance reconnaissance (ISR) imaging sensor range and resolution have long been affected by atmospheric effects. Application of new technology and techniques are expected to solve these limitations enhancing future A2/AD applications. Key is to implement this technology through processing modifications and minor upgrades to the Air Force's (AF) inventory of airborne sensors.

Conventional image techniques are inadequate for extending the useful range of passive optical sensors. Phenomena, such as atmospheric transmission, scatter, dispersion, and turbulence limit and systems capabilities. Advances in adaptive optics have shown that much can be done to mitigate atmospheric turbulence. However, many techniques employ a laser-generated guide star, or other active sensing technique to measure the impact of turbulence along the imaging path. Passive techniques are more desirable to the AF due to their inherent covertness.

Computational imaging has shown promise for improving system performance. The intensive computational burden associated with current techniques may reduce or even eliminate any system volume savings and add additional system power consumption. Mathematical image processing techniques, such as “blind deconvolution” and “luck look,” have also shown promise for mitigating turbulence. However, they can be slow and require considerable computational support to execute.

An investigation of a union of computational imaging and passive adaptive optics techniques to overcome limitations due to atmospheric turbulence is desired. The greatest challenge is that the combination of the two technologies has yet to show an improvement in imaging performance over computational techniques alone. Approaches must be a combination of optical hardware and image processing software. Software only or processor hardware only approaches are not desired and will be considered non-responsive. Systems shall operate in “real time” (10 frames per second minimum, with 60 frames per second and higher desirable) but also improve still images. The technology developed shall be able to be integrated into existing, legacy imaging systems with as little effort as possible. Some allotment for space, weight, and power in system integration must be made. Systems minimizing the integration impact are preferred. Technical approaches shall function in atmospheric windows between 0.38 and 2.5 microns in wavelength. The goal shall be to operate across as broad a spectral bandwidth as possible. The ability of the system to mitigate turbulence and recover useful imagery shall exceed the ability of blind deconvolution techniques when run on the same data at the same frame rate using similar processing hardware.

Sensor observation ranges and altitudes of interest are those relevant to the A2/AD environment (at least 80 km slant range and 35,000 ft above sea level). Hufnagel Valley (5/7) turbulence in conjunction with a “mid-latitude summer” atmosphere will be considered a minimum the approach shall mitigate. Imagery through turbulence will not be provided by AF. The offerer will need to show the ability to simulate or have access to appropriate imagery collected at relevant ranges and through levels of atmospheric turbulence. If the offerer proposes the use of real imagery, they must provide detailed information about the atmospheric conditions under which the imagery was captured (including but not limited to date, time, location, weather, and some measurement of turbulence).

Sensor parameters relevant to the analysis include an 11-inch aperture, a 1-degree field of view, and a 1-meter ground resolved distance.

PHASE I: Concept refinement and high fidelity theoretical analysis. This analysis shall show that the prototype will meet the requirements outlined above.

PHASE II: Detailed design and prototype fabrication. The prototype shall be robust enough for laboratory and limited field testing.

PHASE III DUAL USE APPLICATIONS: Install prototype system in operationally representative aircraft and demonstrate capability at operational ranges. Imaging enhancements will have utility in law enforcement, especially from airborne platforms. Some of the technology will also be applicable to commercial high-end videography.

REFERENCES:
1. Levin, A., Weiss, Y., Durand, F., Freeman, W., “Understanding and evaluating blind deconvolution algorithms,” IEEE, Computer Vision and Pattern Recognition, 2009.

2. Fish, D., Brinicombe, A., Pike, E., “Blind deconvolution by means of the Richardson–Lucy algorithm,” J. Opt. Soc. Am. A, Vol. 12, No. 1, January 1995.

3. Tyson, R., "Principles of Adaptive Optics," CRC Press, Taylor and Francis Group, Boca Raton, FL, 2011.

KEYWORDS: passive imaging, turbulence mitigation, computational imaging, adaptive optics, anti-access, area denial, 2A/AD

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AF141-180 TITLE: FLIR/3D LADAR Shared Aperture Non-mechanical Beam Steering

KEY TECHNOLOGY AREA(S): Sensors

OBJECTIVE: Develop and demonstrate revolutionary technologies for shared aperture non-mechanical steering of 3D LADAR for target acquisition, identification, and tracking which steer SWIR LADAR imagery while passing MWIR for FLIR sensors.

DESCRIPTION: 3D-Laser Detection and Ranging (LADAR) sensor can provide an image to help identify a target hidden in camouflage or ground clutter. 3D information provides clutter separation, adjustable view angles and other cues to isolate and identify targets. Range separation also allows use of energy that "pokes through" gaps in camouflage or foliage. The primary aperture on Electro-Optic (EO) sensor platforms can support both ShortWave InfraRed (SWIR) and MidWave InfraRed (MWIR) sensors. One sensor configuration has a MWIR Forward Looking InfraRed (FLIR) camera coupled with a SWIR 3D-LADAR. Due to lower pixel counts, the 3D-LADAR has a restricted Field of View (FOV) to provide enough resolution for identification. The Concept of Operations (CONOPS) for this system enables a pilot to designate a target from the FLIR, track and image the target with the FLIR at boresight and use a 3D-LADAR for enhanced identification. An improvement to this system adds a non-mechanical steering element to provide the 3D-LADAR unrestricted access to the FOV of the FLIR, which also gives random access to 3D-LADAR steering and the potential for simultaneous multiple target designation and tracking. A revolutionary approach is to eliminate the need for the 3D-LADAR to be constrained to the pointing direction of the gimbal. A non-mechanical beam steering (NMBS) device located at the EO aperture would be able to steer outside of the field of regard (FOR) of the telescope. Such a system provides advances in the capabilities of the EO sensor by allowing the LADAR to operate semi-independently of the FLIR. Independent operations would allow the 3D-LADAR to perform automated functions when not actively engaged with the pilot. The most obvious benefit is that with a wider FOV than the telescope, the 3D-LADAR can track targets even as they leave the FOR of the telescope. A more important advantage is that the 3D-LADAR could continue to collect data even as the primary gimbal is re-tasked. This allows the 3D-LADAR to aggregate data from multiple look angles, enhancing the 3D imaging by illuminating shadowed regions and forming a more complete representation of the target. In wide area 3D imaging, this system improves the area coverage rate by using less mechanical steering which has unusable non-linear regions at the edges of rotation.

Commercial 3D mapping would benefit from multi-spectral capability and increased area coverage rate.

Current NMBS devices are <50mm in size and operate at single wavelengths with little information on multispectral compatibility.

The goal is to develop a non-mechanical steering system capable of steering narrow-band SWIR that is transparent to MWIR. The system design has the NMBS located at the EO aperture, however designs could include NMBS both at the aperture and behind the primary telescope. The SWIR 3D-LADAR wavelengths of interest are 1, 1.5, and 2 micron. The MWIR band of interest is 3-5 micron. The system should steer one of the SWIR wavelengths and be transparent to the entire MWIR band of interest. The steering system should be capable of scaling to 6” apertures. The steering system should be capable of steering 45 degrees off-boresight. Steering does not need to be continuous and can be limited to a discrete number of steer points. MWIR transparency is critically important and the goal is >90% transmission. SWIR steering efficiency is important and should be greater than >80%.

Government materials, equipment, data or facilities are not necessary.

PHASE I: In this initial phase, device concepts will be developed, evaluated, and computer modeled. Design challenges and trade-offs will be tabulated and areas in need of additional research and development will be identified. Projections will be made for the performance of the device. Preliminary designs should be developed for Phase II.

PHASE II: Prototype devices will be constructed and the steering efficiency at SWIR and transparency to MWIR will be measured and evaluated against the program goals. Compatibility tests should be performed with a 3D LADAR and FLIR imager during active steering to ensure compatibility. Iteration on designs and improvements will be made as the production process is refined and preliminary designs for a phase III device should be made.

PHASE III DUAL USE APPLICATIONS: A refined version of the design will be built, focusing on showing the best possible transmission and steering efficiencies. The current manufacturing process will be evaluated and refined to improve yield while reducing cost. A demonstration 6” aperture device will be built and tested.

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2. "Numerical Analysis of Polarization Gratings using Finite-difference Time-domain Method," Ch Chulwoo and Michael J. Escuti, Physical Review A, Vol 76, No. 4, 043815, 2007.

3. Resolution Enhanced Sparse Aperture Imaging, Miller et. al, IEEE Aerospace Conference Proceedings, V 2006, 2006 IEEE Aerospace Conference, 2006, p 1655904.

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KEYWORDS: optical phased array, 3D, LADAR, flash imaging, non-mechanical, beam steering, image steering, mosaic, mosaic imaging, tiled, tiled imaging, LIDAR, FLIR, MWIR, SWIR, polarization

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AF141-181 TITLE: Enhanced Compute Environment to Improve Autonomous System Mission Capabilities

KEY TECHNOLOGY AREA(S): Air Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Aircraft system applications need 5-10 times the computational power currently available. Achieving autonomous operation will require enhanced computing that is resource efficient, flexible, & provides guaranteed capability to ensure mission success.

DESCRIPTION: Intelligence, Surveillance, and Reconnaissance (ISR) assets continue to expand the amount of data collected as sensor technologies improve. They also tend to be smaller, unmanned systems. These conditions require solutions to the problems of transmitting data/information to ground control stations through data links or post-processing raw data into some smaller packages of information on-board. There is a proven value in having real-time or near-real-time interpretation of sensor data. This enables actions to be initiated in a timelier manner. Focusable compute power of this nature can enhance the autonomous capability of systems particularly those guided by a distant operator.

Previous efforts have addressed the data transmission issue. However, these communication pipelines cannot be expanded enough nor can the raw data be compressed enough to solve the problems. Identified solutions were not amenable to retrofitting existing systems and would have to wait for the next new system.

This SBIR will focus on the on-board compute environment and assume that the existing external communication links will be used. A cloud-like computing environment should enable flexible application of processing power to multiple needs and platforms. Different mission legs have different computational requirements. The virtual nature of the cloud should permit addressing these requirements as they dynamically arise during any mission.

A cloud-like capability could combine the best of traditional embedded systems with cloud-like capabilities such as those available in today's high-performance ground based computer.

Issues that need to be addressed include (but are not limited to):
Method of physical implementation
Cloud Communications schema
Data gathering/collecting/processing schema
Security approach(es)/issues

PHASE I: The Phase I work will develop the concept(s) for the cloud computing environment and will, as a minimum, examine the feasibility of the concepts(s). If a single focused concept is proposed, as opposed to a "study of possible concepts," demonstration implementation can begin.

PHASE II: Phase II should include, as a minimum, fabrication of a representative prototype of the concept to demonstrate the performance, security, feasibility, availability analysis, and non-disruption feasibility of the concept.

PHASE III DUAL USE APPLICATIONS: Secure cloud computing environment for use by any DoD organization; can be for a wide variety of data types. Secure cloud computing environment for commercial applications, such as communications, utility or financial firms, or disaster response organizations.

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KEYWORDS: cloud computing, internal cloud communications, autonomous system, cloud security

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AF141-182 TITLE: Real Time, Long Focal Length Compact Multispectral Imager

KEY TECHNOLOGY AREA(S): Sensors

OBJECTIVE: Develop a long focal length multispectral infrared (IR) imager that produces real-time spectral video and is compact compared to current optical systems.

DESCRIPTION: This topic seeks to develop a long focal length, multispectral IR imager that produces real time spectral video (25 to 30 Hz video frame rate) and is compact compared to current optical systems (less than 25lbs). The imager should have a minimum 256 x 256 pixel spatial resolution, four (4) or more spectral colors, minimum of 100 mm focal length, and operate at or near video frame rates. Current IR multi-spectral imagers are large and difficult to integrate on small size, weight, and power (SWaP) limited platforms, such as Puma, Shadow, and Tube Launched Expendable UAS (TLEU). The deficiency of these imagers is their large optical systems which are needed to simultaneously collect both the spatial and spectral data. The optics often form > 90 percent of the total system size. In addition, as the wavelength range and spectral resolution of the imager increases, so does the imager volume. Recently, fabrication techniques have been developed to produce high performance micro-optical elements, such as lenses, filters, gratings and prisms. These micro-optical elements form the core of the optical train for a multispectral imager and their incorporation into a system would vastly reduce the overall system size. Multispectral IR imagers that are available with small SWaP are limited to short focal lengths, restricting their suitability for long range intelligence surveillance reconnaissance (ISR).

Multispectral IR imagers are required that can support long-range ISR applications, while maintaining their compact features. Government materials, equipment, data, or facilities are not required.

PHASE I: Develop a preliminary design of the long focal length, compact, multispectral IR imager that includes all of the relevant sensor parameters. Conduct a study that describes the expected sensor performance based on these parameters. The sensor parameters and study should be of sufficient detail that a customer will be able to determine the compatibility of the sensor approach to their application.

PHASE II: Build a prototype long focal length, compact, multispectral imager that operates in an infrared wavelength band with military relevance and demonstrate performance in simulated operational environment. The imager should have a minimum 256 x 256 pixel spatial resolution, four (4) or more spectral colors, minimum of 100 mm focal length, and operate at or near video frame rates.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR can transform both military and civilian imaging and identification systems.

REFERENCES:

1. C. Gimkiewicz, D. Hagedorn, J. Jahns, E.-B. Kley, and F. Thoma, Fabrication of Microprisms for Planar Optical Interconnections by Use of Analog Gray-Scale Lithography with High-Energy-Beam-Sensitive Glass, Applied Optics, 38, (1999), p. 2986.

2. A. Akiba, K. Iga, Image Multiplexer Using a Planar Microlens Array, Applied Optics, 29, (1990), p. 4092.

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KEYWORDS: optics, multispectral imaging, long focal length

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AF141-183 TITLE: Robust Hyperspectral Target Reacquisition Under Varying Illumination Conditions and Viewing Geometry

KEY TECHNOLOGY AREA(S): Information Systems Technology

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop and demonstrate hyperspectral processing algorithms capable of detection and reacquisition of user-designated surface targets on land (or sea) under various illumination/atmospheric conditions with varying sensor/target viewing geometries.

DESCRIPTION: HSI sensors have the unique ability to identify objects on the earth's surface based on their unique material composition. This may allow detection of designated targets among objects that appear similar to the naked eye. Users of hyperspectral imagery products have a requirement to detect movements of designated targets using subsequent images collected hours to days later. Therefore, a target selected for discrimination in an initial image should be identifiable if it appears in subsequent images, even with changing atmospheric/illumination conditions and under varying observation geometries. Observed target spectral signatures can vary significantly for non-Lambertian objects, such as vehicles, making target detection and/or reacquisition challenging when illumination conditions and/or viewing geometry changes exist between successive images.

Two separate problems should be examined for this effort. In the first problem, the user estimates/extracts a target signature from the scene itself. This signature must then be used to reacquire the same target in subsequent images that may have differences in viewing geometry and/or illumination. The second problem would incorporate a priori bi-directional reflectance distribution function (BRDF) information into the detection/reacquisition algorithms using physical models that can incorporate the BRDF information to achieve improved target detection performance over baseline algorithms that assume Lambertian targets. Additionally, the subsequent images could be acquired by different hyperspectral sensors that may have differences in signal-to-noise ratio (SNR), spectral sampling, ground sample distance (GSD), etc. To address this issue, the algorithms developed must accommodate BRDF characteristics of the target and/or develop methods that are robust to changes in target spectral signatures resulting from these BRDF effects.

The expected development program will make use of available HSI sensor data to explore techniques and algorithms that could enable detection and reacquisition of hyperspectral targets. It would investigate the effects of changes to viewing geometry and target illumination for target materials with reflectance/emissivity characteristics ranging from diffuse to specular.

Investigation of procedures and algorithms for hand-off of targets from one HSI sensor to another is also of interest. A unique spectral signature may allow operators to acquire and specifically identify a given target using more than one sensor. The algorithms developed for robust target reacquisition must be able to accommodate differences in sensor performance, such as spectral resolution, radiometric sensitivity and calibration artifacts.

PHASE I: Develop techniques and algorithms for estimating user-designated target information (i.e., BRDF) from the hyperspectral image itself and develop methods for reacquisition of the target(s) in subsequent images. Demonstrate these techniques on existing HSI data.

PHASE II: Further refine and develop those techniques investigated during Phase I to apply to airborne imagery. Develop techniques and algorithms capable of incorporating a priori BRDF information into the detection and reacquisition of ground targets. Develop and demonstrate an experimental HSI processing system, including a user interface that is easy to learn and operate. Demonstrate the ability to do cross-sensor target reacquisition using airborne imagery.

PHASE III DUAL USE APPLICATIONS: Further refine the Phase II algorithms to produce a prototype HSI software application that can be demonstrated with an operational air or ground system. The prototype software application should be able to operate in real-time in accordance with the sensor data rates.

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KEYWORDS: hyperspectral, imaging, sensor, tracking, HSI

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AF141-184 TITLE: RF Photonic Multiple, Simultaneous RF Beamforming for Phased Array Sensors

KEY TECHNOLOGY AREA(S): Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop an integrated photonic TTD Unit for RF receive-only phased array to enable 8 simultaneous, independent beams with high bandwidth and linearity, low loss, sufficient delay resolution for scanning over +/- 60° with potential for reduced C-SWaP.

DESCRIPTION: Applying new radio frequency (RF) photonic technology to RF collection systems is expected to increase performance by and order of magnitude while reducing Cost, Size, Weight and Power (C-SWaP). Reducing payload C-SWaP is a key objective of Air Force unmanned aircraft systems (UAS). Advances in RF photonic signal processing techniques will allow high-performance RF sensors to use the optical domain for a new generation of RF signal distribution systems.

Simultaneous, multi-user, multi-target tracking RF beamforming technology is a focus for advanced phased-array sensor systems. Fiber-optic True Time Delay (TTD) and more recently the use of optical Wavelength Division Multiplexing (WDM) and Photonic Integrated Circuits (PIC) for RF beamforming has been recognized as having promise for realizing order of magnitude reduction in C-SWaP over electronic approaches, especially with regard to achieving a simultaneous signal tracking capability for multiple high-gain RF beams.

Continued advancement in RF photonic signal processing techniques is needed in order for high-performance RF sensors to take advantage of the optical domain provided by next-generation fiber-optic RF signal distribution systems. This topic involves the study, design, and development of a simultaneous, receive-only, multi-beam RF phased-array Time Delay Unit (TDU) using PIC techniques. The emphasis is on developing architectures and components that optimize simultaneous RF beamforming for eight or more beams with a path toward achieving performance goals needed for high performance sensor systems. State-of-the-art electronic TDUs provide 11-bit TTD (from 2.5 to 511.75 pico sec) and 8-bit attenuation, but lack the potential C-SWaP reduction that photonic techniques provide for simultaneous RF beamforming. For example, a variety of system demonstrations have employed photonic WDM for simultaneous use of the TDU.

The work to date shows promise for even further C-SWaP reduction using PIC to optimize interconnects, active components and fabrication. This effort shall address a TDU for RF multi-beamforming phased-array antenna system to accommodate at least eight simultaneous beams, and each beam should provide the necessary pointing and tracking accuracy over a minimum scan range of +/- 60 degrees with < 2 degrees resolution. The design shall use PIC concepts to reduce the system C-SWaP and provide a producible design. The design shall minimize the need for calibration and tuning and minimize the optical and RF losses through the system. Program goals are to provide an instantaneous bandwidth of at least 1.0 GHz and be tunable over two octaves including coverage in the X-Band. The array size of interest is 64 linear elements and a scalable architecture is desired. Additional performance goals are SFDR = 120 dB Hz2/3 and noise figure <10 dB. The offeror shall describe and discuss the technical challenges in the proposed effort, the enabling technologies required to realize the design, and the innovation(s) in the design.

PHASE I: Design the architecture and components for an RF photonic, receive-only, simultaneous multi-beamforming TDU and evaluate with modeling and simulation. Perform a detailed analysis of the components, their impact on system performance and key technical challenges. Provide a conceptual design of the integrated system including the components and interfaces, C-SWaP, and system performance metrics.

PHASE II: Complete the design as well as address the key technical challenges of the photonic, simultaneous, multi-beamforming receive-only array. Design and fabricate test chips to perform RF and optical tests to characterize performance of the essential components and subsystems which can be used to evaluate the essential metrics necessary to accomplish transition to a Phase III prototype packaged system.

PHASE III DUAL USE APPLICATIONS: Fabricate and test a prototype TTD subsystem for receive-only array. Integrated photonics true-time delay can benefit consumer wideband, wired and wireless gigabit services via wideband tunable delay and phase shifting in synchronous optical networks (SONET) used in the telecommunications industry.

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KEYWORDS: beamformer, true time delay, phased-array, photonics, simultaneous multiple beams

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AF141-185 TITLE: Methodologies for Predicting Dormant Missile Reliabilities

KEY TECHNOLOGY AREA(S): Materials / Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop an accurate line replaceable units (LRU) level reliability prediction model for dormant aging weapon systems and limited maintenance test data.

DESCRIPTION: The Air Force is interested in advancing methodologies that can accurately predict reliabilities of an existing aging dormant weapon system and its LRU. Most particularly, we are interested in predicting when LRU subsystems can be expected to wear out without any remedial action. “Wear out” is when one can expect to see a significant increase in failure rates and decrease in reliability. Knowing in advance of entering the wear-out phase for subsystems can provide lead time for planning supply chain upgrades and modifications to the system. This is very important when considering systems that sit in storage for the majority of their lifetimes and are required to operate at high reliabilities upon immediate use. Nuclear cruise missiles may reside in a dormant state for many years within a needed service life of decades (approximately 30-50 years) and then be required to operate with high reliabilities. The typical environment is for a cruise missile to be stored in a non-environmentally controlled facility for two years as part of a pylon or launcher package, minimally tested at two years as part of the package, returned to storage for two more years, minimally tested again, returned to storage for two more years, then downloaded from the package and undergo maintenance actions (like engine removal and replacement, pyro change out), extensive system level testing, and returned to storage to start the cycle again. Cruise missiles that require minimum maintenance and inspection throughout their lifetimes do not have a methodology to properly predict the reliability of the subsystems. LRUs are defined as separate boxes or items that have a unique purpose within the cruise missile. LRUs can be cables, actuators, panels, sensors, antennas, navigation boxes, batteries, engine, fuel tanks, motors, etc. Required characteristics, for these methodologies include being able to execute via computer code quickly (< 2 hrs.) with use of an industry standard PC, is based on limited maintenance data availability, can use statistical/probability distribution/confidence level processes, mathematics must be sound (i.e., must consider dissimilar data issues), not require any additional weapon system instrumentation while in storage, and can utilize LRU drawings or subject matter expert information for parts count or stress determinations as needed by the methodology. Limited maintenance data availability is defined as having field maintenance test data on certain subsystems once every two years maximum. This data only assesses pass or fail condition for the LRU.

As Phase I efforts, the Air Force would like the consideration and development of several methodologies and evaluation of the effectiveness/accuracy of the reliability predictions for those methodologies. Also, the Air Force would like a description of an approach for future activity to achieve an accurate model for a dormant cruise missile.

PHASE I: Identify and develop methodologies for predicting reliabilities of subsystems using representative data. Identify and evaluate mechanisms for proofing or validating the methodologies. Deliverable is a paper or papers that explain methodologies and mechanisms for validating the methodologies.

PHASE II: Develop prototype computer code model based on Phase I findings and that meets a set of criteria developed. Criteria will be similar as in description above. Demonstrate the accuracy of the computer code to predict reliability of dormant subsystems using representative data.

PHASE III DUAL USE APPLICATIONS: Other industries with systems/subsystems that remain dormant for extended periods of time require high reliability and are being considered for use past their original designed service life. Usable by other dormant systems/subsystems.

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4. RADC-TR-89-276, Dormant Missile Test Effectiveness, Calhoon, et al., Dec 1989.

KEYWORDS: prediction, reliability, methodologies, dormant, subsystems, line replaceable units, nuclear, aging systems, cruise missiles

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AF141-186 TITLE: Advance Tracking Algorithms to Meet Modern Threats

KEY TECHNOLOGY AREA(S): Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Investigate and validate the use of advanced non-linear, non-Gaussian tracking algorithms against targets which are either supermaneuverable, have low radar cross section (RCS) and/or have high scintillation properties.

DESCRIPTION: In the first look, first kill environment against low radar cross section (RCS) targets, tracking ability becomes critical at longer ranges. You want to be able to track at lower signal to noise ratios (SNR) while minimizing the radar beam dwelling on your target. Being able to accurately discriminate the position of a target is problematic in many ways. Most tracking algorithms today work using various versions of the Kalman Filter (KF). Velocity information is radial only, along the line that extends from the radar to the target. Rapid changes in acceleration, high-G turns, or rapid changes in RCS can bring about large errors in the estimates of the tracking algorithm and cause the radar to break lock. These pose problems to conventional trackers because the movement is contrary to the linear motion models assumed by the tracking algorithms. Rapid changes in acceleration can be caused by nonlinear movements such as high alpha maneuvers known as supermaneuverability. Supermaneuverability allows an aircraft to perform maneuvers beyond what is possible by pure aerodynamic forces. It is a trait of some advanced fourth-generation and 4.5-generation fighter aircraft which has become standard in fifth-generation aircraft. These same maneuvers have the potential to cause break-locks of radar-guided missiles by defeating conventional KF trackers assumption of linear motion models. Unmanned aerial vehicles (UAVs) are also highly maneuverable and inherently smaller and harder to detect. UAVs have the potential to pull upwards of 20 Gs as reported by several National Aeronautics and Space Administration (NASA) UAVs.

KF is far from perfect. It evolved at a time when computational power was limited and it performed estimates using linear and Gaussian assumptions. Computational power is no longer limited, but numerous new radars being developed are still using KF for tracking while the target environment has changed dramatically. The mathematical models, used in tracking filters, have to make assumptions about the type of targets anticipated; approximations and unmodelled effects are inherent ingredients. The KF is a set of mathematical equations that provides an efficient computational (recursive) means to estimate the state of a process, in a way that minimizes the mean squared error. The KF is very powerful in several aspects, but the purpose of the filter in radar target tracking is to estimate the state of linear systems using measurements containing random errors. However, RCS scintillation (large rapid changes in signal to noise ratio) and supermaneuverability are not linear or random. RCS of some targets scintillates much more today than they did years ago (target RCS can change by 30 db in a usec.). There are two approaches that have progressively acquired the favor of scientists, engineers and practitioners; they are the Unscented KF and the Particle Filtering (PF). (Particle filters also known as Sequential Monte Carlo (SMC), sequential importance re-sampling (SIR), bootstrap filters, Monte Carlo filters, and condensation filters.) PF has the advantage of being able to handle any functional non-linearity, and system or measurement noise of any distribution. This approach and Track Before Detect (TBD) is much more doable today given the higher sample rates and the increased computational power available today.

PHASE I: Evaluate tracking algorithms for non-linear targets in non-Gaussian environment. Complete trade-off study for various Kalman, particle, and multi-hypothesis filters. Evaluate each approach against various supermaneuverable targets, targets with low RCS, and/or targets with specular scintillation properties. Evaluate TBD algorithms and determine SNR improvements and computational requirements.

PHASE II: Develop, demonstrate, and validate an assessment tool that addresses capability gaps identified in Phase I and provides future radar architecture design performance requirements to acquisition community for tracking and TBD algorithms. Tool will determine performance parameters and determine various sampling, data bandwidths, and computational requirements. Tool can be used to access difficult commercial tracking applications, such as low-level aircraft and non-linear movement of weather.

PHASE III DUAL USE APPLICATIONS: Construct a prototype system (hardware and analysis software) and validate in production representative environment. Follow-on activities include specific application integration and creation of any customer-unique requirements and documentation. Develop commercialization plan and market analysis.

REFERENCES:
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2. "Efficient Particle-Based Track-Before-Detect in Rayleigh Noise," Mark G. Rutten, Neil J. Gordon and Simon Maskell, Intelligence Surveillance and Reconnaissance Division, Defence Science and Technology Organisation, PO Box 1500, Edinburgh, SA 5111, Australia.

3. "Application of Knowledge-Based Techniques to Tracking Function," A. Farina, Alenia Marconi Systems, Italy.

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KEYWORDS: radar, signal processing, nonlinear, tracking, particle filter, kalman filter, track before detection, TBD, RCS, supermaneuverable, scintillation, measurement, signal to noise ratio,

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AF141-187 TITLE: Increased Radio Frequency (RF) Sampling & Radar Architecture Upgrades

KEY TECHNOLOGY AREA(S): Electronics and Electronic Warfare

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Validate the use of analog to digital converters (ADC), with higher sample rates and wider word lengths, to improve radar detection. Explore architecture upgrades which will allow rapid insertion of faster ADC, processor, and bandwidth technology.

DESCRIPTION: In the first look, first kill environment, detection range becomes critical when going up against threats with comparable technology. You want to be able to detect at lower signal to noise ratios (SNRs) while minimizing the beam dwell and the transmitter power of your radar. The modern airspace today includes advanced fourth- and fifth-generation aircraft which have more maneuverable and lower radar cross section. Unmanned air vehicles and unmanned combat air vehicles are also inherently smaller and harder to detect and track.

Detection of small targets in the presence of noise and clutter interference presents a formidable task in a radar system design. The linear dynamic range of RF receivers is a limiting factor in the performance of high-end military radar receiver. The nonlinear distortion generated in the ADC and the analog receiver limits the capability of the backend radar signal processor. The next generation of ADC from major vendors is expected to provide 300 Ms/sec with 16-bit resolution. In the commercial world, the status quo is 14-bit resolution, but in many military systems 10-12 bit is pushing and numerous new radar are only using 10 bits, as discussed in Military Embedded Magazine. Those extra few dBs of resolution will enable receivers, such as radars and Radar Warning Receivers, to perform more effectively. Electronic intelligence (ELINT) equipment can take advantage of the improved resolution to perform single emitter identification more accurately and at greater range. The Electronic Countermeasures world will be able to detect targets earlier and react quickly to encountered threats, thereby improving the Probability of Survival.

In any digitization process, the faster the signal is sampled, the lower the noise floor. The faster a signal is sampled, the lower the noise floor because the noise is spread over more frequencies. The noise floor (referenced to the full scale value of the ADC) is: Noise Floor (dBFS) = $6.02 * \text{Bits} + 1.76 + 10 \text{ Log } (\text{Fs}/2)$. SNR of the ADC may be greatly improved by filtering just the bandwidth of the desired signal. Therefore, the SNR is proportional to 10 Log (Fs/Filter BW). The greater the ratio between sample rate and filter bandwidth, the higher the SNR.

Dynamic range is critical to increased radar performance, especially in the case of passive target detection using signals of opportunity. Transmitting any RF energy is dangerous in a modern threat environment, so passive technology is becoming an emerging technology for airborne radars. Here dynamic range alone is critical in order to separate the much weaker reflected signal from the direct path broadcast signal of opportunity.

Various techniques can be implemented to improve the sampling rate beyond the capability of a single ADC semiconductor. Many techniques, such as interleaving ADCs, stacked ADCs, and the use of nonlinear gain stage, were tried years ago and have not been researched in the current environment of much faster floating point Field

Programmable Gate Arrays (FPGAs), mezzanine cards, faster data busses, and much faster multicore, parallel processors. Interleaving ADCs and synchronizing them should be easier today given the speed and gate count of modern FPGAs. Many of these other techniques were tried in the past because nothing else worked. Today, we need to explore what can be done to maximize the sample rate, dynamic range, and upgradeability for modern airborne radars up against the new emerging threats.

PHASE I: Quantify the theoretical dependencies of ADC sample rate and dynamic range on resolution, SNR, gain, and tracking ability in various radar configurations. Evaluate sampling multiple times per pulse using various waveforms and the impact on single pulse Doppler determination, cross-correlation, unambiguous range, de-ghosting, multi-path discrimination, and electronic protection.

PHASE II: Develop parameter assessment tool which helps acquisition community predict performance. Assess which sampling techniques for transmitted and received waveforms are compatible with various radar architectures. Evaluate various acquisition board architectures which can keep pace with bandwidth and sample rate improvements. Recommend novel architecture designs which will allow rapid insertion of faster ADC, data bus, and processor technology taking into account SWAP-C for airborne radar.

PHASE III DUAL USE APPLICATIONS: Construct a prototype system (hardware and analysis software) and validate in production representative environment. Follow-on activities include specific application integration and creation of any customer-unique requirements and documentation. Develop commercialization plan and market analysis.

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KEYWORDS: radar, signal processing, analog to digital converter, ADC, sampling, detection, dynamic range, quantization, measurement

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AF141-190 TITLE: SATCOM Wideband Digital Channelized Receiver with Low-cost Silicon Technology

KEY TECHNOLOGY AREA(S): Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors

are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop a low cost, silicon-based wideband receiver that down-converts and digitizes multiple satellite bands simultaneously for digital multi-channel decoding to boost throughput and reception quality.

DESCRIPTION: Current satellite communications (SATCOM) systems such as Wideband Global Satellite (WGS) [1] requires multiple channel radio frequency (RF) receivers to decode and are therefore bulky and high cost. Recent research [2][3][4] focuses on the superconductor based, mixed-signal data converter to achieve high sample rate digitization in the satellite front-end. However such systems are expensive and bulky due to the use of cooling. There are also other all-digital approaches [5] available, by focusing primarily on the digital processing; however, they do not offer an integrated, low-cost solution.

This SBIR is looking for a system that reduces the number of channels in the RF receiver into a wideband receiver and down-converts and digitizes all channels with an integrated compact digitizer using low-cost silicon technology. This topic will support WGS or its successor - the channels will not be coherent with respect to each other. The 2 Gsps is a stretch from the present 400 MHz capability but is a goal. The required effective number-of-bits (ENOB) threshold for this sampling rate is 10 bits. References are listed for state-of-the-art analog-to-digital converter parts with an ENOB of 10 bits and sample rate greater than 2 Giga-samples per second (GSps) [6,7]. The goal is to reduce size, weight, and power (SWAP) and provide enhanced capabilities to the following digital baseband and MAC processing to utilize the simultaneously down-converted digital channels to enhance throughput and/or reception quality. In addition, requirements on part reliability to enable a 15-year mean mission duration is needed; needing a total radiation tolerance > 30 krad (Si). A holistic approach that utilizes signal processing to enhance the digitization with high bit resolution and high sample rate > 2 Gsps is desired. References are provided for state-of-the-art commercial off-the-shelf (COTS) analog-to-digital converters with ENOBs of 10 bits and sample rate greater than 2 Gsps [6,7]. Such holistic approach may include sophisticated digital calibration using blind source separation or equalization. The proposed system should be mode-agnostic, e.g., communications on the move or communications at the halt over wideband satellite communication channels.

PHASE I: Investigate circuit, architecture, and processing algorithms to determine the feasibility of producing a wideband digital channelized receiver.

PHASE II: Develop and demonstrate a prototype wideband digital channelized receiver.

PHASE III DUAL USE APPLICATIONS: Military Application: directly digitize an entire block of satellite bands for various military systems such as advanced extremely high frequency (AEHF), WGS, and GBS. Commercial Application: satellite set-top boxes that enable simultaneous tuning of multiple channels.

REFERENCES:

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2. D. Gupta, et. al., "Digital Channelizing Radio Frequency Receiver," IEEE Transaction on Applied Superconductivity, Vol. 17, No. 2, June 2007.

3. S. Sarwana, et. al., "Multi-band Digital-RF Receiver," IEEE Transaction on Applied Superconductivity, Vol. 21, No 3, Jan. 2011.

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5. H. Beljour, et. al., "Proof of Concept Effort for Demonstrating an All-digital Satellite Communications Earth Terminal," IEEE 2010 MILCOM.

6. From company e2V: (http://www.e2v-us.com/products-and-services/hi-rel-semiconductor-solutions/broadband-data-converters/evaluation-boards/?e2vredirect)

e.g.#1: EV10AS150B-EB EV10AS150-EB 10-bit 2.6Gsps ADC with 1:2/4 DMUX evaluation board
e.g.#2: EV10AS152A-EB EV10AS152-EB 10-bit 3Gsps ADC with 1:2/4 DMUX evaluation board.

7. From TI Devices: (http://www.ti.com/lsds/ti/data-converters/high-speed-adc-greater-than-1gsps-products.page#p84=10;12&p1089=2000000000;5000000000)
e.g.#1: ADC12D1800RF - 12-Bit, 1.8/3.6 GSPS RF sampling ADC
e.g.#2: ADC12D1600RF - 12-Bit, 2.0/3.2 GSPS RF sampling ADC.

KEYWORDS: satellite communications, wideband, RF, digital receiver, down-converter

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AF141-191 This topic has been removed from the solicitation.

AF141-192 TITLE: Affordable E-band Radiation Hardened Mixed Mode Microelectronics

KEY TECHNOLOGY AREA(S): Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop and demonstrate affordable E-band (71-76 and 81-86 GHz) analog-to-digital converters (ADCs) and digital-to-analog converters (DACs) suitable for satellite communications application.

DESCRIPTION: Over several decades advances in miniaturization have caused breakthroughs in digital microelectronics (notably ADCs and DACs), which promote system-on-chip (SoC) solutions to radio frequency (RF) analog and digital functionality. The recent rapid integration of mixed-mode microelectronics has enabled communications systems programmability through software or software radio (SR) to increasingly displace conventional hardware-based radio systems. While satellite designers are typically confronted with a set of ambitious payload performance requirements, limited launch vehicle lift capability constrains the payload size, weight and power consumption. Improvements in affordable mixed mode microelectronics device performance offer one means of implementing SR, increasing the level of functionality of future generations of communications satellites while meeting budget constraints. Challenges facing analog/mixed signal integrated circuit designers include higher bandwidth and frequency ratios, form factor, power consumption, and die area. Satellite communications (SATCOM) mixed-mode applications are particularly acute in the area of front end processing. E-band (71-76, 81-86 GHz) wireless systems offer higher data rates and long distance transmissions suitable for SATCOM. The goals of this topic are to develop ADCs and DACs to support RF front ends that downconvert to baseband for SR in space applications. The specifications for these circuits include space-qualified ADCs or DACs that operate up to 1 GHz input bandwidth, resolution up to 12 bits, effective number of bits (ENOB) of 9 bits at 1 GHz, extended operating temperature range (-40 to +80 deg. C), and 1 Mrad(Si) total dose radiation tolerance. A trade study should include potential cost, size, weight and power (C-SWAP) reductions for application-specific integrated circuit (ASIC) development over commercial off-the-shelf (COTS) approach. Additional objectives include improved power efficiency, increased bandwidth, reduced microcircuit footprint, reduced noise, and enhanced reliability.

PHASE I: This phase will perform a trade study on novel ADCs and DACs radiation-hardened architectures. Design and demonstrate the feasibility of fabricating radiation-hardened ADCs and DACs for insertion into an E-band RF-front end. Conduct modeling and simulation where appropriate to validate design.

PHASE II: Fabricate prototype ADCs and DACs and characterize for relevant metrics, including power consumption, radiation hardness, bandwidth, and mean time to failure through accelerated life testing.

PHASE III DUAL USE APPLICATIONS: Military: Communications/navigation satellites, avionics and ground terminals. Commercial: Commercial satellites, commercial avionics, and wireless telecommunications.

REFERENCES:

1. T. Okamura, C. Kurioka, Y. Kuraishi, O.Tsuzuki, T. Senba, M. Ushirozawa, and M. Fujimaru, “10-GHz Si Bipolar Amplifier and Mixer IC's for Coherent Optical Systems,” IEEE J. Solid-State Circuits, Vol. 27, pp. 1775-1779, Dec. 1992.

2. S. P. Voinigescu and M. C. Maliepaard, “5.8 GHz and 12.6 GHz Si Bipolar MMIC's,” IEEE Int. Solid-State Circuits Conf. Dig. San Francisco, CA, pp. 372-373, Feb. 1997.

KEYWORDS: microcircuit, nanoscale, integrated circuit, radiation hardened, mixed mode, submicron, affordable

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AF141-193 TITLE: V-Band Traveling Wave Tube Amplifier with Extended Output Power

KEY TECHNOLOGY AREA(S): Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop a space-qualifiable traveling wave tube amplifier (TWTA) operating at 71 to 76 GHz, capable of providing at least 100 Watts of output power and suitable for long term geostationary earth orbit (GEO) missions.

DESCRIPTION: Providing warfighters with a comprehensive understanding of battlefield situational awareness depends on the timely delivery of the Airborne Intelligence, Surveillance, and Reconnaissance (AISR) data. With proliferation of new generations of unmanned aerial vehicle (UAV) platforms capable of hosting satellite communications payloads, it is becoming increasingly advantageous to access additional spectrum in the millimeter wave region to transfer high resolution AISR data between UAVs and satellites. The development of a new generation of high power TWTAs capable of accessing spectrum between 71 and 76 GHz will enable a high data rate downlink from a satellite located in geostationary earth orbit (GEO) to ground sites. The GEO satellite can be a high data rate relay for beyond the line-of-sight (BLOS) communications between users and one or more UAVs loitering above the weather. The Air Force is interested in developing a new set of power amplifiers capable of supporting future generations of bandwidth efficient modulation waveforms, as well as allowing access to spectrum in the 71 to 76 GHz range. Aside from raising the output power, the TWTA design should strive to optimize self interference, adjacent channel interference, effective isotropic radiated power (EIRP), and output backoff. Goals include the capability to support 12/4 quadrature amplitude modulation (QAM) with 30 dB suppression and no more than 3 dB amp backoff, and an objective of 32 QAM, 36 Db suppression, with 3 dB amp backoff; power added efficiency (PAE) > 50 percent, operating temperature range -40° to + 80° C, space qualification, and radiation hardening goals of a total dose tolerance up to 1 Mrad (Si).

PHASE I: Develop a TWTA design consistent with goals and objectives identified above. Validate design the modeling and simulation.

PHASE II: Fabricate one or more prototypes and characterize for all relevant performance parameters including frequency bandwidth, PAE, and EIRP.

PHASE III DUAL USE APPLICATIONS: Military TWTA applications include space- and terrestrial-based radio frequency (RF) bandwidth efficient communications. Commercial TWTA applications include avionics, space and terrestrial RF applications where high data rates and bandwidth efficiency are needed.

REFERENCES:
1. A. Katz, R. Gray, and R. Dorval, “Performance of Microwave and Millimeter Wave Power Modules (MPMs) with Linearization,” in Proc. 2005 IEEE Military Communications Conf., Atlantic City, Oct. 17–20, 2005, pp. 2693–2699.

2. R. J. Barker, R. Luhmann, N.C. Booksc, and G. Nusihovich, "Modern Microwave and Millimeter Wave Power Electronics," Hoboken, NJ: Wiley-IEEE Press, 2005.

3. J. Weekley and B. Mangus, “TWTA versus SSPA: A Comparison of On-Orbit data,” IEEE Trans. Electron Devices, Vol. 52, pp. 650–652, May 2005.

4. A. Katz, R. Gray, and R. Dorval, “Wide/multiband Linearization of TWTAs Using Predistortion,” IEEE Trans. Electron Devices, Vol. 56, No. 5, pp. 959–964, May 2009.

KEYWORDS: traveling wave tube amplifier, EIRP, power amplifier, satellite communications, linearity, power added efficiency, AISR

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AF141-194 TITLE: Noise Canceling Rad Hard Extremely High Frequency (EHF) Low Noise Amplifier

KEY TECHNOLOGY AREA(S): Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop innovative techniques to minimize noise introduced during the signal amplification in satellite low-noise amplifiers (LNA) operating between 20.2 to 21.2 GHz.

DESCRIPTION: Signal noise poses a significant challenge to long-distance satellite communications, impacting bit error rates, the level of transmitter radiated power required to close the link, and, indirectly, the payload size, weight and power. Ongoing research in noise cancellation has demonstrated the use of noise cancellation to enhance noise performance. The purpose of this topic is to develop innovative low-noise amplifier (LNA) design techniques to cancel and otherwise minimize noise introduced during the signal amplification process. Typically, each receive module has a LNA and a phase shifter that have been integrated into one, or more, Monolithic Microwave Integrated Circuits (MMICs). In order to increase receiver sensitivity while reducing the power dissipation of the receiver, there is a critical need to minimize additional noise introduced by the LNA while maximizing power efficiency. While the dissipation in the LNA is a small fraction of the prime power consumption, the receive antenna generally remains powered at all times, thus the power consumption in the receiver represents a critical power drain. Excessive LNA power increases heat-load, which in turn, increases the required cooling of the receive phased array antenna. Because LNAs play a critical role in high data rate satellite warfighter communications, the Air Force is interested in sponsoring noise canceling research to both reduce noise figure and power consumption with the prerequisite linearity to support bandwidth efficient modulation waveforms like 16-Quadrature Amplitude Modulation (QAM). This topic is intended to support research exploring the best approach to achieving noise canceling with optimum linearity (measured by the output third-order intercept point, or OIP3, across the frequency of operation) and demonstrate the level of performance that can be achieved in low-noise amplifiers for satellite application at 20.2 to 21.2 GHz. Goals include noise figure (NF) <1.5 dB, small signal gain >30 dB, low power consumption, high linearity, operating temperature range -40 to +80 deg C, and 1 Mrad(Si) total dose radiation tolerance.

PHASE I: Perform trade study of device technologies for low-noise amplifiers at 20.2 to 21.2 GHz. Design and demonstrate the feasibility of fabricating EHF LNA. Conduct modeling and simulation where appropriate to validate design.

PHASE II: Fabricate one or more prototype EHF LNA devices and characterize for operating band, small signal gain, noise figure, operating temperature range, and radiation characteristics.

PHASE III DUAL USE APPLICATIONS: Military: Military applications include terrestrial wireless communications, avionics, and satellite communications. Commercial: Commercial applications include wireless communications, avionics, and telematics.

REFERENCES:

1. F. Bruccoleri, E.A.M. Klumperink, and B. Nauta, “Wide-band CMOS Low-Noise Amplifier Exploiting Thermal Noise Canceling,” IEEE Journal of Solid-State Circuits, Vol. 39, pp. 275-282, Feb. 2004.

2. S. Blaakmeer, E. Klumperink, D. Leenaerts, and B. Nauta, “Wide-Band Balun-lna with Simultaneous Output Balancing, Noise-Canceling and Distortion-Canceling,” IEEE Journal of Solid-State Circuits, Vol. 43, pp. 1341-50, June 2008.

3. M.T. Reiha and J.R. Long, “A 1.2 V Reactive-Feedback 3.1-10.6GHz Low-Noise Amplifier in 0.13 μM CMOS,” IEEE Journal of Solid-State Circuits, Vol. 42, pp. 1023-1033, May 2007.

KEYWORDS: low noise amplifier, thermal noise, signal processing, low-noise optimization, extremely high frequency, EHF, satellite, noise cancellation

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AF141-195 TITLE: Characterization of Atmospheric Turbulence for Long Range Active Electro-Optic Sensors

KEY TECHNOLOGY AREA(S): Sensors

OBJECTIVE: Develop methods and devices to characterize atmospheric turbulence and its effects on the performance of long-range active electro-optical sensors.

DESCRIPTION: Atmospheric optical turbulence can have deleterious effects on the data quality of active sensors. Most current turbulence measurement systems give path integrated turbulence metrics (for example, atmospheric coherence diameter). Some systems are able to characterize the atmosphere at intermediate points along a path but are not well suited to a dynamic flight environment. Active coherent laser sensors operating near the earth are more sensitive to atmospheric turbulence than passive non-coherent imaging due to the cumulative effects of variations of piston, and their sensitivity to changes of the measured phase. A full understanding of atmospheric optical turbulence, its spatial and temporal coherence attributes and their effects on coherent laser radar systems (e.g., scintillation, beam wander, beam breakup, etc.) is desired to improve the performance of current and future intelligence, surveillance, and reconnaissance (ISR) optical systems and their models. Without an in-situ measurement of the turbulence experienced by these sensors, understanding their performance is difficult. Characterization parameters measured in flight and along the line of sight to the target include but are not limited to: refractive index structure function parameter, Rytov number, atmospheric coherence width, iso-planatic patch size, turbulence assessment at various locations along the path, aero-optic characterizations, and pertinent weather variables (temperature, humidity and their gradients, pressure, wind, etc.). Systems capable of measuring these atmospheric parameters from both ground and airborne locations and at ranges of many tens of kilometers are desired.

Information gained by the development of atmospheric turbulence devices will be used to develop highly detailed physics-based models of the atmosphere, its effects on active imaging, and ways to mitigate the effects both in hardware and software. Knowing the underlying causes of image degradation due to atmosphere activity could then be used to extrapolate and predict performance in other types of atmospheres (for example, Mid-Atlantic, desert, arctic, etc.)

This topic seeks to develop atmospheric characterization techniques to determine the amount of phase errors introduced and their spatial and temporal correlations. Techniques for mitigation of the atmospheric phase may require knowledge of the atmosphere for benchmarking of mitigation techniques and sensor characterization.

PHASE I: Plan, analyze, and design systems capable of characterizing and assessing atmospheric optical turbulence and its effect on the performance of coherent ladar systems in air-to-air, air-to-ground, and ground-to-ground scenarios.

PHASE II: Develop prototype system (employing the design of Phase I) to measure required parameters to properly characterize atmospheric turbulence in air-to-air, air-to-ground, and ground-to-ground scenarios. Minimizing the technology as small as possible is desired. Airborne demonstrations are preferred but ground-based demonstrations are acceptable. This technology has non-military applications: NASA space observations and imaging, NOAA earth imaging, and data for adaptive optics applications.

PHASE III DUAL USE APPLICATIONS: The end-products of this solicitation will be applicable to many of the laser-based systems under development by the Air Force Research Laboratory and across the Department of Defense. Commercial applications include wind/turbulence sensing for commercial airports' landing advisories.

REFERENCES:
1. Andrews, L. C., & Phillips, R. L. (2005). Laser Beam Propagation Through Random Media (2nd ed.). Bellingham, WA: SPIE.

2. Doviak, R. J., & Zrnic, D. S. (2006). Measurements of Turbulence and Observations of Fair Weather. Doppler Radar and Weather Observations (2nd ed., pp. 386-505). Mineola, NY: Dover Publications.

3. Karr, T. J. (2003). Resolution of Synthetic-Aperture Imaging Through Turbulence. JOSA-A, 1067-1083.

4. Karr, T. J. (2007). Atmospheric Phase Error in Coherent Laser Radar. IEEE Transactions on Antennas and Propagation, pp. 1122-1133.

5. Frehlich, R. G., & Kavaya, M. J. (1991). Coherent Laser Radar Performance for General Atmospheric Refractive Turbulence. Applied Optics, pp. 5325-5352.

KEYWORDS: turbulence, optical turbulence, index of refraction structure function, scintillometer, synthetic aperture ladar

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AF141-196 TITLE: Hybridization Techniques for Ultra-Small Pitch Focal Plane Arrays

KEY TECHNOLOGY AREA(S): Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Design, develop, and demonstrate high yield, reliable, reproducible, and affordable hybridization techniques for ultra-small (< 5 µm) pitch infrared focal plane arrays (IRFPAs).

DESCRIPTION: At the heart of virtually every infrared (IR) imaging system there is a sensor (the focal plane array) that detects and converts the incoming infrared radiation into an electrical signal in order to form an image. This focal plane array (FPA) is comprised of two components, the detector array and the readout integrated circuit. The detector array is the infrared-sensing part of the sensor and can be made from a wide variety of materials that are sensitive in the wavelength band of interest. The readout integrated circuit (ROIC) is the signal processing component and is generally fabricated on a silicon substrate using volume production integrated circuit processes. Once each component is fabricated and functionality is verified, they are mated physically and electrically through an indium bump hybridization process to form a focal plane array.

Persistent surveillance IR imaging systems are in wide use within the U.S. Air Force. These systems are incorporated into a wide variety of aircraft, from unmanned aerial vehicles at low altitudes to satellites that operate in space. These systems typically employ staring FPA technology, sometimes up to multi-megapixel geometries. They allow for wide area surveillance and are a critical tool for our warfighters. Through the years, there has been a push towards higher resolution in order to resolve smaller features at higher altitudes. In order to maintain the aperture size of the existing optics with increased resolution, the only option is to decrease the existing detector pixel spacing (pitch). Current indium bump bond technology is used on both the ROIC and detector array assemblies down to a pitch of around 12 µm with almost 100 percent yield.

There is a need to establish a FPA hybridization concept that allows for high yield, reliable, reproducible, and affordable interconnects for < 5 µm pitch IRFPAs. Pushing the pitch to this level is a huge challenge since the ROIC and detector arrays are seldom made of the same material, meaning that they may have vastly different coefficients of thermal expansion. In addition, the detector array may have issues such as wafer bow, variations in total thickness, and can be made of materials that are soft, delicate, or difficult to handle.

Innovative hybridization approaches to achieve < 5 µm square pixel pitches using a silicon ROIC mated to a variety of detector materials (to include HgCdTe, GaAs, GaSb, and InSb at a minimum) are being sought. Z-technologies with multi-level interconnects are being pursued elsewhere and will not be considered under this topic. Candidate methods shall be thoroughly characterized to determine overall interconnect yield and shall undergo a series of temperature cycling (300K to 77K) and other reliability tests to determine the effect on interconnect yield.

PHASE I: The contractor will conduct a study of detector materials to determine material properties in comparison to silicon ROICs. The contractor will then develop appropriate candidate approaches that can be used with a variety of detector materials using techniques that are compatible with standard IRFPA processing methods. A small scale test chip shall be demonstrated at the conclusion of Phase I.

PHASE II: Using the designs developed in Phase I (with optimization), the contractor will design, fabricate, and demonstrate multi-megapixel FPA test chips that employ a variety of detector material test chips (to include HgCdTe, GaAs, GaSb, and InSb at a minimum) that are hybridized to dummy silicon ROIC chips. These hybrid arrays will then be characterized for interconnect yield and will then be subjected to a series of reliability tests in order to determine the integrity of the < 5 µm interconnects.

PHASE III DUAL USE APPLICATIONS: The contractor will team with an FPA producer to demonstrate this technique on an operational FPA. Comparisons between this and standard methods will be carried out. This technology will be applicable to a variety of applications requiring high density, small pitch, reliable interconnects.

REFERENCES:
1. John, J. et al., "High-Density Hybrid Interconnect Methodologies," Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Vol. 531, Issues 1–2, (2004), p. 202.

2. Jiang, J. et al., “Fabrication Of Indium Bumps For Hybrid Infrared Focal Plane Array Applications,” Infrared Physics & Technology, Vol. 45, Issue 2, p. 143 (2004).

3. Rogalski, A., "Progress in Focal Plane Array Technologies," Progress in Quantum Electronics, Vol. 36, Issues 2-3, p. 342 (2012).

KEYWORDS: hybridize, focal plane array, infrared, readout, photodetector

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AF141-197 TITLE: Novel Signal Processing for Airborne Passive Synthetic Aperture Radar

KEY TECHNOLOGY AREA(S): Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US

Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop innovative techniques and algorithms for airborne passive synthetic aperture radar (SAR) imaging using terrestrial commercial transmitters as sources-of-opportunity.

DESCRIPTION: As military and commercial transmitters continue to multiply, the availability of dedicated spectrum for radar applications continues to degrade. Furthermore, contested, or anti-access/area-denial (A2/AD) environments limit the survivability of platforms employing active radar systems. Combined with the potential for reduced size, weight, and power (SWaP) requirements, these considerations motivate the use of passive radar for imaging of ground targets. Interest in passive radar has increased dramatically in recent years, although the majority of the work has focused on airborne moving target indicator (AMTI) using ground-based receivers. Recent experiments [1], have looked at airborne receivers for MTI. In addition, SAR images have been formed from airborne platforms using radar satellites as illuminators [2] and from stationary receivers using navigation satellites as transmitters [3]. A few efforts have explored the use of commercial terrestrial illuminators for imaging [4]. Finally, limited algorithmic development has explored imaging from airborne platforms using commercial illuminators [5]. The state-of-the-art in passive imaging allows high-resolution images to be formed using radar illuminators, but only limited progress has been made in forming high- resolution images using commercial sources of opportunity, particularly when considering an airborne receiver. AFRL has recently funded work in combining signals from multiple commercial illuminators to improve AMTI and GMTI performance. This effort seeks to extend this work for imaging applications.

In particular, this effort addresses the potential to enhance platform survivability in A2/AD environments by forming high-resolution images of ground targets suitable for Automatic Target Recognition (ATR) using passive radar. The focus is on imaging using non-pulsed, terrestrial, commercial sources of opportunity using an airborne receiver. These sources are typically narrowband and illuminate the terrain at low grazing angles and with relatively wide beams. Thus, signals from multiple transmitters across multiple frequency bands will need to be combined to obtain the bandwidth and spatial diversity required for forming images of sufficient resolution for military applications. Techniques leveraging such multistatic configurations should account for expected target fluctuations across this spatial aperture. Novel imaging schemes to exploit sparse representations and to leverage other forms of prior knowledge may also prove beneficial if justified by a proposed concept of operations. Schemes which leverage multiple receive channels on a single platform or multiple coordinated receive platforms could also be considered to improve system performance. The proposed approaches should identify and improve standard image metrics, with a particular emphasis on obtaining high-resolution images using commercial illuminators. This capability would represent a substantial improvement over current state-of-the-art performance enabling passive radar for tasks previously limited to active radar systems.

A limited data set may be provided by the government as part of Phase II. No government materials, equipment, data, or facilities will be provided under Phase I.

PHASE I: Define performance metrics for high-resolution airborne passive SAR imaging. Conduct a trade study to select a set of illuminators to exploit for the effort. Develop innovative image formation algorithms and techniques tailored to the selected illumination sources. Validate the proposed imaging scheme through simulation.

PHASE II: Mature the techniques developed in Phase I to support operation across multiple bands and multiple transmitters. Address practical implementation concerns including autofocus, direct path cancellation, and other potential challenges identified during Phase I. Demonstrate and validate the developed techniques on either measured or high-fidelity simulated data.

PHASE III DUAL USE APPLICATIONS: Transition opportunities for this effort include ongoing passive radar efforts at AFRL and other government labs as well as UAV and aircraft program offices. Potential commercial applications include law enforcement and low-cost SAR mapping.

REFERENCES:
1. IEEE Aerospace and Electronic Systems Magazine, Volume 27, Issues 10-11, 2012.

2. Rodriguez-Cassola, M.; Baumgartner, S. V.; Krieger, G., and Moreira, A., “Bistatic TerraSAR-X/F-SAR Spaceborne--Airborne SAR Experiment: Description, Data Processing, and Results,” IEEE Transactions on Geoscience and Remote Sensing, Vol. 48, No. 2, pp. 781-794, 2010.

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4. del Arroyo, J. R. G. and Jackson, J. A., “SAR Imaging Using WiMAX OFDM PHY,” Proc. IEEE Radar Conf. (RADAR), 2011, pg. 129-134.

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KEYWORDS: passive, SAR, A2/AD, algorithms, signals-of-opportunity

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AF141-198 TITLE: Aperture Synthesis for Partially Coherent and Passive Illumination

KEY TECHNOLOGY AREA(S): Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop electro-optic (EO) infrared (IR) sensors using aperture synthesis for partially coherent and passive illumination, providing increased resolution with reduced sensor volume and speckle noise.

DESCRIPTION: In order to perform tactical identification (ID) and intelligence surveillance and reconnaissance (ISR) missions at longer standoff ranges, better sensor resolution is required. Currently, resolution of EO/IR sensors is limited by sensor clear aperture due to the associated volume, as well as the coherence diameter for the path through the atmosphere. Techniques which enable larger effective apertures with reduced sensor size weight and power (SWaP) and the ability to mitigate atmospheric turbulence are required to increase sensor resolution. Aperture synthesis enables a larger monolithic aperture to be replaced with a number of smaller sub-apertures, with a reduction in volume approaching the ratio of the sub-aperture diameter to the system aperture diameter. Synthesis techniques are also compatible with compensation for atmospheric turbulence, whether through digital phasing of sub-apertures, or through hardware means such as adaptive optics.

The current state of the art for passive aperture synthesis in systems with large fields of view utilize techniques based on Fizeau interferometry, where images from multiple telescopes are coherently combined. This requires hardware to correct for any piston and tilt phase errors to a fraction of a wavelength, which becomes problematic for turbulent atmospheres and large fields of view. Anisoplanatism due to the atmosphere requires different phase corrections between apertures for different patches of the field of view. The complexity of correcting for each isoplanatic patch using hardware is untenable, making a computational solution highly desirable. Coherent systems can readily perform such corrections digitally, but suffer from speckle noise effects and short coherence times due to target instability at optical wavelengths. Systems using active illumination can further increase the size of a synthesized aperture through the use of multiple transmitters, for both coherent and partially coherent illumination.

An innovative solution is desired that enables digital aperture synthesis techniques to be used with either short-wave infrared (SWIR) or mid-wave infrared (MWIR) illumination that has a large fractional bandwidth, enabling sensors to use a greater portion of the reflected light from an area of interest. Techniques which employ multiple sub-apertures in order to reduce sensor size in addition to multiple transmitter locations to increase the effective system aperture are preferred. Systems which are compatible with both active and passive illumination are also desired, where active illumination may provide higher resolution while passive illumination may be used to view a larger area of interest. Techniques should be efficient in terms of required signal, with illumination and exposure requirements approaching those of an ideal aperture equal in size to the system's synthesized aperture. Applications of interest are performing ID and ISR missions from a flight environment with the system integrated into a pod or EO turret. Sensor should be capable of operating in atmospheric profiles consistent with up to 3 times Hufnagel-Valley 5/7, standoff ranges greater than 40 km for active illumination, and standoff ranges greater than 100 km for passive illumination.

PHASE I: Investigate innovative approaches and model performance for potential airborne applications. All key aspects to the imaging functionality should be modeled to determine signal to noise ratio (SNR), turbulence, exposure time, and detector noise that enable successful aperture synthesis. Foundational experiments to verify theoretical concepts should also be conducted.

PHASE II: Mature design and develop brassboard demonstrations for aperture synthesis techniques. Design shall include requirements for all key subsystems, such as sensor array, laser transmitter, and receiver optics. Brassboard demonstrations should verify functionality in turbulent atmospheres and confirm models used to determine system requirements.

PHASE III DUAL USE APPLICATIONS: Develop hardware suitable for integration in an airborne platform and demonstrate ability to perform synthesis in relevant atmosphere for large fields of view. Dual-use applications include commercial imaging and surveillance for ground-, air-, and space-based systems.

REFERENCES:
1. Bertero, M. et al, “Imaging with LINC-NIRVANA, the Fizeau Interferometer of the Large Binocular Telescope: State of the Art and Open Problems,” Inverse Problems, Vol. 27, (2011).

2. E. L. Cuellar, James Stapp, and Justin Cooper, "Laboratory and Field Experimental Demonstration of a Fourier Telescopy Imaging System," Proc. SPIE 5896, Unconventional Imaging, 58960D, (September 01, 2005).

3. R. Fiete, T. Tantalo, J. Calus, and J. Mooney, “Image Quality Assessment of Sparse Aperture Designs,” Applied Image Pattern Recognition Workshop, Vol. 0, p. 269, 2000.

4. J. Marron and K. Schroeder, "Holographic Laser Radar," Opt. Lett. 18, pp. 385-387 (1993).

5. David J. Rabb, Douglas F. Jameson, Jason W. Stafford, and Andrew J. Stokes, “Multi-Transmitter Aperture Synthesis,” Optics Express Vol. 18, pp. 24937-24945 (2010).

KEYWORDS: aperture synthesis, sparse apertures, electro-optic imaging, ladar, laser radar

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AF141-199 TITLE: Optical Isolator for Infrared (IR) Applications (2-15 micron)

KEY TECHNOLOGY AREA(S): Electronics and Electronic Warfare

OBJECTIVE: Identify, develop and demonstrate materials and techniques based on the magneto-optic effect or nonlinear processes, which can realize nonreciprocal response for optical isolation in Short-IR, Mid-IR, and Long-IR laser applications (2-15 micron).

DESCRIPTION: The optical spectrum from Short Wave Infrared (SWIR) (1-2 micron) and Mid Wave Infrared (MWIR) (3-8 micron) to Long Wave Infrared (LWIR) (8-15 micron) is known for covert and eye-safe operation, for the thermal vibrations of molecules (used in sensing and thermal imaging), ladar applications, etc. New military and sensing applications are expected to drive the IR laser market in the next few years. "Mid-Infrared Lasers 2010" report published by Strategies Unlimited summarizes that the new market segments will grow approximately 30% per year, compounded annually through 2014. There are many military sensors applications that require optical isolation at 2 micron wavelength, such as Tm-doped high-power fiber laser systems. Also, there is a need in developing MWIR high-power laser systems for electronic warfare (EW) applications, such as infrared countermeasures (IRCM), in which the laser sources may be spectrally or coherently combined in order to achieve the required performance.

High-performance laser systems must be protected from unwanted back reflected light, which may destabilize the laser or even damage the internal laser cavity. An optical isolator is a device that is used for this purpose since it transmits light in a particular direction while blocking the light in the opposite direction. Commercially available optical isolators are limited to the visible and near-IR spectra and are based on the magneto-optic effect (Faraday effect). These devices may be polarization sensitive, typically for free space laser coupling, or polarization insensitive, which are used in fiber optics applications. Materials that exhibit very strong magneto-optic properties include Indium Antimonide (InSb) and Mercury Telluride (HgTe), both of which may be used in MWIR and LWIR. However, present materials systems and geometrical structures may need to be improved to avoid the need for cryogenic cooling and to deal with thermal lensing effects at high powers. For standard Faraday rotation approaches, polarizing elements in the IR range may need to be developed for isolation purposes. Other approaches that may be used to create an unidirectional propagation of the light are based on nonlinear optical processes, in which a nonreciprocal response can be realized. On-chip optical isolation based on the magneto-optic nonreciprocal phase-shift effect has also been explored in the near-IR spectrum and may be extended to the MWIR for optical waveguide on-chip applications. Therefore, there is an opportunity to develop new materials and techniques for optical isolation in the 2-15 micron wavelength range, for which commercial products do not exist.

In more sophisticated configurations, the optical isolation may become an integral part of the laser system (or integrated on a single chip), which provides unique properties such as superior wavelength stability, ultrafast optical modulation, and all-optical processing. An example of such systems may be injection locked quantum cascade lasers operating in the MWIR spectrum. These applications will open new horizons for all-optical computing, high data rate free space optical communications, IR spectroscopy, etc. Thus, there is a need for new materials and techniques for optical isolation in the 2-15 micron wavelength range.

Cooling is essential in high-power IR optical isolators. At those wavelengths, about 20% of the optical input power is lost inside the Faraday rotator and then released as the heat. Also small size, weight and power (SWaP) must be considered for airborne systems applications.

There will be no Government-furnished equipment for this project.

PHASE I: Develop materials and techniques suitable for constructing an optical isolator based on the magneto-optic effects, time-dependent modulation, and/or nonlinear processes. Strongly asymmetric transmission should be achieved in the 2-15 micron spectrum for free space and/or wave-guide setting, including on-chip solutions. A free-space design should account for thermal management at high powers.

PHASE II: Using the results from Phase I, fabricate and demonstrate a device capable of transmitting the light in one direction while blocking the light in the opposite direction with return loss of up to 30-40 dB at power levels of up to 500W. The device may be free space, fiber coupled, polarization sensitive or polarization independent. Identify and propose a design, which will allow for broadband operation of the optical isolator.

PHASE III DUAL USE APPLICATIONS: Based on the results of Phases I and Phase II, develop and demonstrate an on-chip fiber-coupled broadband optical isolator in the 2-15 micron spectrum with return loss of 40 dB or better and insertion losses of less than 5 dB.

REFERENCES:

1. Lei Bi, et al, "On-chip optical isolation in monolithically integrated non-reciprocal optical resonators," Nature – Photonics, 5, 758 (2011).

2. Eli Yablonovitch, "One-way road for light," Nature, 461, 744 (2009).

3. J. Fujita, et al. Optical isolation based on nonreciprocal phase shift in a Mach–Zehnder interferometer, Appl. Phys. Lett. 75, 998 (1999).

4. H. Lira, et al, Electrically Driven Nonreciprocity Induced by Interband Photonic Transition, PRL 109, 033901 (2012).

5. D. Dai et al, Passive technologies for future large-scale photonic integrated circuits on silicon, Light: Science & Applications, NATURE.com/lsa (2012).

KEYWORDS: mid wavelength infrared (IR), long wavelength infrared, laser, optical isolator, optical diode, faraday effect, magneto-optic effect, nonlinear optics

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AF141-203 TITLE: Improved LHE Zn-Ni and Cd Plating Process

KEY TECHNOLOGY AREA(S): Air Platforms

OBJECTIVE: Show feasibility of reduced Hydrogen Embrittlement relief post-plate bake times for cadmium, chromium and ZnNi on high strength steel landing gear parts. The current industry standard is a 23 hour bake; much shorter bake times are desired.

DESCRIPTION: Relief baking and plating operations are currently required by LHE (low hydrogen embritteling) MIL-STD-870 (cadmium plate), USAF drawing 201027456 (Zn-Ni plating) and MIL-STD-1501 (Chromium plate). Recent HE testing has shown that hydrogen can effectively be relieved with much lower final bake times. Lower bake times represent a significant savings to the USAF and industry in terms of processing hours and cost.

To demonstrate safety of flight with reduced bake time, the following required qualification tests will be accomplished on 260-280 Ksi UTS 4340 HSS test coupons:
• Hydrogen Embrittlement (ASTM F519-05)
• Stress Corrosion Cracking (ASTM E 1681 or approved equivalent)

The HE testing standard will be a 200 hour (75% NFS) sustained tensile stress test. HE coupon testing will utilize test samples of 4340 high strength steel (260-280ksi). Currently the only facility applying LHE ZnNi plating per USAF drawing 201027456 is located at Hill AFB. All parameters and results will be recorded and reported. All test procedures and test criteria shall be coordinated and approved by the USAF requirements office and be accomplished according to approved industrial standards with deviations approved by the TPOC. This project has applicability to all commercial /industry plating operations utilizing LHE varieties of cadmium and ZnNi plating. All test plans and data results will be subject to customer review and expert panel review (ASTM F.07 HE committee), at the discretion of the TPOC.

The following required qualification tests will be accomplished High Strength Steel (HSS) including Aermet 100, 4340, S53 and possibly 300M test coupons and landing gear components to determine a safe minimum post bake time for HSS:

• Adhesion and Paint Adhesion (ASTM B571)
• Hydrogen Embrittlement (ASTM F519)
• Fatigue (ASTM E466)
• Corrosion (ASTM B117)
• Stress Corrosion Cracking (TBD)

Before the testing is begun and design of experiments will be conducted, after which the test plan will be finalized. If the result of the qualification tests support the reduction of plating post bake times, LHE Zn-Ni plating specification USAF DWG. 201027456, Chrome specification MIL-STD-1501, and Cad specification Mil-STD-870 will be updated to reflect the reduced post plating bake time.

PHASE I: Each F 519 sample group will be cad plated, and tested as described above with varying bake times utilized. Sample groups shall consist of 4-8 specimens. At a minimum; sample group bake times will vary 1, 1.5, 2, 3, 4, 8 and 23 hours. The process will be repeated for LHE ZnNi plated specimens. All samples shall be pulled to failure after the HE testing is complete.

PHASE II: Testing outlined in phase one will be repeated based on a rigorous design of experiments approach. Additional testing will be accomplished chromium plate added to additional groups of ZnNi and Cad plated coupons. Testing will also include comparative stress corrosion cracking resistance (per ASTM E 1681 or approved equivalent) and general corrosion. Anomalies noticed in phase I will also be re-evaluated/defined and possibly re-tested; thicker material sections will also be considered.

PHASE III DUAL USE APPLICATIONS: Will be implemented by the USAF if justified. Acceptance by industry through ASTM F.07 Hydrogen Embrittlement Committee review.

REFERENCES:

1. AF Dwg 201027456.

2. MIL-STD-1501.

3. MIL-STD-870.

KEYWORDS: LHE Zn-Ni Plate, Chrome plate, Cad Plate, Hydrogen Embrittlement, Landing Gear

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AF141-204 TITLE: Improve Energy Source for NDI Equipment Tools

KEY TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Design, develop, and create an improved energy source that can be used as the primary power source for Eddy Current (EC) and Ultrasonic (UT) nondestructive testing inspection (NDI) equipment currently in use throughout the Air Force.

DESCRIPTION: Nondestructive testing equipment in the AF is normally used in flight lines and hangars where current use of batteries are required but are costly and require daily recharging. EC and UT equipment currently in use in the AF has the options of using Lithium-ion, NiMH, NiCAD, or Alkaline battery in any of this equipment.

Transport and disposal of spare batteries is a shipping and environmental cost to the AF. With the advances in technology in the utilization of alternate power sources such as solar energy and fuel cell designs, there is a good possibility that other forms of energy power can also be used as the primary power source for AF NDI equipment. The goal is to reduce costs of electrical consumption, eliminate use of harmful toxins that destroy our environment, increase portability and usability of equipment, increase utilization of instruments at deployed locations, and increase safety of personnel. Considering the numbers of this equipment in the AF, cost savings and reduction of hazardous materials can be significant.

Research feasibility and applicability of improved alternate energy source to current battery configurations as source of power supply for EC and UT NDI equipment currently in use in the AF. Design a new alternate source that could be used interchangeably between EC and UT NDI equipment. Research capability of alternate source design that will have high capacity and operating time as long as if not longer than the most efficient storage battery currently in use. Validate and verify performance of new alternate source when used for EC and UT NDI equipment.

PHASE I: Research the operating parameters for the various NDI hand tools noted above and develop concept design for utilizing new energy capability to replace existing required battery sources in the hand tools. Phase I report should describe details of the design; necessary test plans and performance parameters, demonstrate power requirements and how proposed solar power design can be accomplished.

PHASE II: Based on approved design approach from Phase I, develop working prototypes for the selected models and perform validation testing IAW Test Plan from Phase I with users in AFSC and field groups.

PHASE III DUAL USE APPLICATIONS: If this project will prove successful, it will flow throughout the nondestructive testing industries such as aerospace, oil, auto, construction, and others where NDI is a major factor and the same and similar types of NDI equipment are used.

REFERENCES:

1. Tech Order 33B-1-1 (Nondestructive Inspection Methods, Basic Theory).

2. Tech Order 33B-1-2 (Nondestructive Inspection General Procedures).

3. Nortec 2000 Dual Eddyscope Operation Manual (Eddy Current Unit).

KEYWORDS: Alternative Energy, NDI, Eddy Current, Ultrasonic

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AF141-205   TITLE: Non-Destructive Inspection for Medium Caliber Gun Barrel Fatigue Crack

KEY TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Development of a non-destructive inspection (NDI) for medium caliber gun barrels to assess the presence and severity of fatigue cracks in the barrel walls.

DESCRIPTION: Barrels have a variety of failure modes that must be monitored over the life of a barrel. Each barrel type typically has a driving failure mode that dictates the replacement schedule that must be adhered to when fielded. Fatigue cracking is one of the more critical failure modes that must be prevented as it will result in a catastrophic barrel rupture. This is typically prevented by assigning a maximum rounds count to the barrel set. This mandatory replacement point is the worst case crack growth rate with an appropriate safety factor applied. However, most barrel sets do not see these worst case conditions therefore more life could be gleaned from most barrels sets if a means of accurately determining fatigue crack length could be developed.

An NDI method is being sought after that will accurately and reliably assess fatigue cracking in gun barrels and compare it against a maximum allowable crack length. The new method would require the barrel wall to be assessed throughout its thickness and over its entire length. The machine must automatically compare any cracks found to the given limits with little to no manual intervention. The machine will preferably be portable, such that it can be used on flight lines without removing barrels from the aircraft. In addition, it is also preferred that is technology be incorporated into existing laser bore mapping equipment, such that all barrel inspections can be accomplished through one machine.

Currently, a method in which existing NDI equipment can be used to assess barrel wall fatigue cracking is unknown. This project will most likely require new equipment to be developed to accomplish the crack assessment along with new procedures for the use of the new equipment. This project may potentially require the coordination of the contractor with USAF testing facilities and the loaning of USAF barrels for inspection testing. The technical point of contact will coordinate the required access to USAF testing facilities.

PHASE I: Develop the ability to accurately and reliably detect fatigue cracks in medium caliber gun barrels. Define the resolution, defect detection and localization with sub-mm accuracy.

PHASE II: Demonstrate the non-destructive evaluation of cracking in barrels and comparison against crack limits with complete autonomy other than manpower necessary to interface the machine with the barrel.

PHASE III DUAL USE APPLICATIONS: Incorporation of the NDI equipment into existing bore mapping equipment.

REFERENCES:
1. Title: Measurement and Inspection of Gun Tubes AD Number: ADA270439 Corporate Author: ARMY TEST AND EVALUATION COMMAND ABERDEEN PROVING GROUND MD Personal Author: (Not Available). Report Date: May 14, 1993 Media: 47 Page(s).

2. Title: Eddy Current Inspection of Gun Tubes, AD Number: ADA256065 Corporate Author: ARMY ARMAMENT RESEARCH DEVELOPMENT AND ENGINEERING CENTER WATERVLIET NY BENET WEAPONS LAB Personal Author: Concordia, David Report Date: July 01, 1992 Media: 45 Page(s).

KEYWORDS: gun barrel, gun barrel inspection, nondestructive testing, nondestructive evaluation

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AF141-206 TITLE: Nonparametric Recurrent Event Data Analysis

KEY TECHNOLOGY AREA(S): Information Systems Technology

OBJECTIVE: Provide a capability for analysis/evaluation of usage and event data of fielded repairable parts/systems. This capability will provide “ility” performance measures to identify trends and the ability to determine root cause and best course of action.

DESCRIPTION: The required knowledge, software tools and resources to analyze and/or evaluate usage and event data are not generally available across the USAF enterprise. The reasons for this lack of availability are complex and varied. These reasons include inadequate component reliability/health metrics, legacy data architectures lacking sufficient indenture, and a lack of understanding that appropriate statistical analysis is a reliability improvement tool.

Historically, Mean Time Between Failure (MTBF), not Mean Cumulative Function (MCF), has been the component reliability/health metric used by the Air Force. Mean Time Between Failure (MTBF), is too lagging to be actionable in the best case, and is not representative of actual system reliability in the worst case. Although the necessary usage and event data is being collected, these data are not readily accessible. When mature, this project will provide reliability analysts access to current Air Force data systems, a full suite of data and statistical analysis tools and the understanding to access and utilize usage and event data in new and powerful ways. Weapon system engineers and supply chain professionals will have fully integrated access to the data and tools necessary for early identification and analysis of those data trends, outliers, and anomalies indicating potential areas of focus for studies and/or corrective action in the repair process.

This notice is intended to insure that any software that is developed will be able to pass Government certifications so the software can be used on Government Networks. If the research effort includes computer systems that meets the requirements of the 2005 National Defense Acquisition Act (NDAA) (10 U.S.C 2222(j)(2)) the following shall be required: an outline during the Phase I R&D effort such that compliance with 10 U.S.C 2222(j)(2) can be accomplished at the point of commercialization (SBIR III). If the project successfully transitions to Phase II, the outline will be used to assist the contractor and government with the documentation necessary to secure National Defense Authorization Act (NDAA) approval. The SBIR PH I NDAA Outline shall be further developed during the Third Quarter of the Year 1 PH II SBIR project such that all documentation required for NDAA can be completed. All documentation for compliance with NDAA 10 U.S.C. 2222(j)(2) shall be accomplished by the Seventh Quarter of the Year 2 PH II SBIR project. The NDAA documentation is required prior to SBIR PH III Commercialization.

PHASE I: Use current software/data management capabilities as a baseline to define the requirements of a new or improved data analysis and data management software package and provide a final report outlining system requirements, flexibility and customizability of parameters, data, and data fields, and Air Force system compatibility assessments. NDAA requirements possible, see above Description for details.

PHASE II: Develop & demonstrate a new or improved data analysis and management software package that provides software tools and resources to evaluate usage and event data from current Air Force Systems to find trends, outliers, or anomalies in the data and provide information to reliability analysts as potential areas of focus for studies and/or corrective action in the repair process. The system must have flexible/customizable parameters, data, and data fields, and be compatible with AF Systems.

PHASE III DUAL USE APPLICATIONS: Implement the data analysis and management software package into Air Force sustainment activities. Import historic usage and event data into the package with parameters provided by the program office and provide output in the form of recommended focus areas for repair of the part/system.

REFERENCES:
1. N. S. Trindade D, "Statistical Analysis of Field Data for Repairable Systems," 2008.

2. W. B. Nelson, Recurrent Events Data Analysis for Product Repairs, Disease Recurrences, and Other Applications, Alexandria: ASA-SIAM Series on Statistics and Applied Probability, 2002.

KEYWORDS: Nonparametric, Performance, Software, Repair data, trend analysis

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AF141-207 TITLE: Residual Stress Determination for Cold Expanded Holes

KEY TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: To develop a method to verify the coverage and intensity of cold working processes on materials of interest to the Air Force.

DESCRIPTION: The Air Force and industry partners perform many manufacturing processes with the aim of inducing residual stress in metals to prevent the onset of fatigue induced cracking. Cold working of metal alloys to create localized compressive residual stresses can greatly improve fatigue behavior, particularly in areas of stress concentration. Further, the application of compressive residual stress on the leading edge of compressor or fan blades can reduce an engine's susceptibility to foreign object damage (FOD). In fatigue loading, compressive residual stresses effectively lower the mean net stress state. Therefore, locations such as fastener holes can greatly benefit from compressive residual stresses, as they tend to mitigate the effects of the geometric stress concentration at that location. In a FOD situation, this can prevent a crack from growing from a damage site.

Despite the known benefits of cold working techniques, there are limitations in the ability to non-destructively inspect its characteristics and analyze the associated component longevity benefits in fatigue applications. Many of the quality assessment techniques used with cold working rely on witness samples and process controls. Assessment is not made on the component, which requires the assumption that the processing of the component and sample are the same. The conservatively necessary in assuming the similarity between process samples and the component itself requires that full credit cannot be given in design calculations to the benefits of the treatment process. Current non-destructive techniques have significant limitations. For example, x-ray diffraction is only able to measure the stress state at the surface of the material, ignoring sub-surface material, and cannot be used in some materials of interest to the Air Force. Further, several of these cold working techniques only alter the appearance of a treated area subtly. Even verifying a treatment was applied can be difficult.

Consequently, a methodology is being sought to quantify the effectiveness of cold working processes on the components themselves. A method that can non-destructively verify the intensity and coverage of a treatment will provide valuable information to the Air force and associate industry partners. This information represents valuable input to structural integrity analyses, to accurately take into account the improved fatigue life properties that are attributed to the cold working process. The resulting benefits of the developed methodology are widespread, and include improving the frequency of expensive inspection intervals by improving predictive lifetime techniques.

PHASE I: Develop the basis of an assessment technique that can evaluate coverage and intensity of cold working treatments on materials of interest to the Air Force and how it could be verified through coupon level testing during Phase II of the development.

PHASE II: : Develop a prototype cold work evaluation apparatus and develop related software algorithms that will implement the framework from phase I. Demonstrate a procedure for using the prototype to acquire data and show how that data can be used to improve predictive maintenance programs.

PHASE III DUAL USE APPLICATIONS: Deployment to other critical applications would be available in private industry, which arise in the civil aviation, automotive, railroad, heavy equipment, chemical, oil drilling and refining, construction and medical industries.

REFERENCES:
1. T. Nicholas, J.P. Barber and R.S. Bertke "Impact Damage on Titanium Leading Edges from Small Hard Objects." Experimental Mechanics (1980): Vol.20, No.10, pp.357-364.

2. Prevey, Paul S., and John T. Cammett. "The Effect of Shot Peening Coverage on Residual Stress, Cold Work and Fatigue in a Ni-Cr-Mo Low Alloy Steel. LAMBDA RESEARCH CINCINNATI OH, 2000.

3. Vasudevan, Vijay K., et al. Structural Technology Evaluation Analysis Program (STEAP). Task Order 0029: Thermal Stability of Fatigue Life-Enhanced Structures. CINCINNATI UNIV OH, 2012.

4. Roy, A. K., et al. "Residual stress characterization in structural materials by destructive and nondestructive techniques." Journal of Materials Engineering and Performance 14.2 (2005): 203-211.

5. Jayaraman, N., et al. "Case Studies of Mitigation of FOD, Fretting Fatigue, Corrosion Fatigue and SCC Damage by Low Plasticity Burnishing in Aircraft Structural Alloys". Proceedings of USAF Aircraft Structural Integrity Program (ASIP), Memphis, TN, Nov. 29-Dec. 1, 2005.

KEYWORDS: Residual Stress, Cold working, CBM, Material State Awareness, Fatigue Mitigation, Foreign Object Damage, Nondestructive Evaluation Methods

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AF141-208 TITLE: Material and Process Specification Optimization

KEY TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Design, develop, and qualify specifications and processes required for procurement and application of materials that meet the weapons systems quality requirements, reduces cost and improves efficiencies.

DESCRIPTION: As part of the overhaul and repair process for aircraft gas turbine engines, Landing Gear and other critical parts, the repair depots routinely apply large amounts of thermal spray coatings for use in substrate repair build-up, wear, corrosion resistance, thermal barrier and chrome replacement coatings. These coatings are applied at a high cost to the Department of Defense in terms of materials and manpower. In addition to the high cost of coating materials, application of the coatings requires expensive consumable materials including fuels, power and thermal spray equipment components. Other major costs include masking, calibration/maintenance of the spray equipment, laboratory metallurgical testing, reworking of parts that do not meet metallographic requirements, engineering time supporting unacceptable coatings, determining cause and rework. Quite often the needs of the warfighter are jeopardized by inability to supply engine or landing gear components due to failure to determine quality of spray during application of coatings. Additionally, AF programs such as High Velocity Maintenance (HVM) requirements and current/future budgetary constraints are forcing improvements in efficiencies and reduction in waste for the coating processes in the application shops. For example, rework of an engine component normally costs several thousand dollars each time it is recycled. The specifications that are currently used to procure coating feedstock allow acquisition of non-usable materials that fail to meet rigid metallurgical laboratory requirements and result in unacceptably applied coatings. Also, the current set of process parameters do not perform acceptably when used with all materials from all vendors when purchased with the current material specification. To meet the needs of the warfighter and to achieve the requirements of AF budget reductions, a new set of material and process specifications are needed for AFSC Complexes that will eliminate purchase of non-usable raw coating materials, reduce application process variation and reduce the amount of metallurgical laboratory testing required.

PHASE I: Perform research methodology that can identify and characterize all currently used thermal spray materials, vendors, processes, success/failure rates and associated loss or wasted costs in Air force. Demonstrate the applicability of the test and analysis plan by evaluation on a family-type of material and application systems that is compatible to those used in the AFSC Complexes.

PHASE II: Perform testing and analysis per plan of Phase I to define, develop, and qualify the new set of material and process specifications needed for procurement and application of materials that meet rigid metallurgical test requirements at the Air Force ALC’s. Deliverable will be: A) new set of material specifications, B) new set of process parameter specifications, C) laboratory data supporting those specifications.

PHASE III DUAL USE APPLICATIONS: A reliable set of specifications could be used throughout the thermal spray industry worldwide to improve quality, improve efficiency and reduce overall cost of ownership.

REFERENCES:

1. Maria Oksa, et al., “Optimization and Characterization of High Velocity Oxy-fuel Sprayed Coatings: Techniques, Materials, and Applications”, Coatings 2011, 1, 17-52.

2. John P Sauer, et al., “Improved Thermal Spray Consistency Via Plume Sensors -An Aerospace Perspective”, ASM International Thermal Spray 2009: Expanding Thermal Spray Performance to New Markets and Applications, May 2009, 878-882.

KEYWORDS: thermal spray, HVOF, plasma, wire spray, thermal barrier, metallurgical

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AF141-209 TITLE: Dimensional Evaluation of Aircraft Fuel Cells

KEY TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Provide improved technologies for the dimensional evaluation of aircraft fuel cells.

DESCRIPTION: Aircraft fuel cells are flexible rubber-coated fabric enclosures for the containment of fuel within aircraft cavities. The overall envelope dimensions and locations of interface fittings and attachment elements such as lacing ferrules and hanger baskets are critical to the proper function and durability of the fuel cells. Some applications consider these components Critical Safety Items and their dimensional characteristics are critical features.

The existing method of dimensional inspection is to install the fuel cells in a facsimile structure and evaluate the fit of the cell within the facsimile structure. This approach is sensitive to the installation methodology used and does not directly produce quantitative dimensional data. It also requires large, expensive tooling and is labor-intensive.

The critical technological innovation desired as a result of this project is a means of directly measuring dimensional data for fuel cells. Methods which lessen fixturing, labor, and training requirements and improve repeatability will be regarded as especially desirable.

Benefits of a capability to perform dimensional evaluation of aircraft fuel cells will improve the identification of bladder issues prior to installation and provide a quality evaluation of supply assets. This will result in lower risk of in-flight emergencies and improve higher reliability of remaining assets.

Potential applications of such a technology include multiple military and commercial aircraft systems, military and commercial land and sea vehicles, and additional military and commercial applications utilizing flexible container liners with critical interfaces.

PHASE I: Develop an innovative technology, methods and approach that will provide a means to directly measure aircraft fuel cells. Provide a final report that provides the results of the technical approach and describes the concept demonstration for Phase II. The approach should show application to multiple aircraft configurations.

PHASE II: Based on the outcome of Phase 1 concept demonstration, develop the technology for a prototype system that demonstrates the capabilities involved and establishes repeatability for two or more aircraft configurations. Test the prototype system in a real-world environment and obtain MIL-SPEC approval for use of the process within Air Force Material Command (AFMC).

PHASE III DUAL USE APPLICATIONS: A dimensional measurement test for fuel bladders has applications across the AF inventory including many helicopters as well as many commercial aircraft.

REFERENCES:
1) Basic Fuel Requirements, http://www.faa.gov/regulations_policies/handbooks_manuals/aircraft/amt_airframe_handbook/media/ama_ch14.pdf.

2) DoD Audit Report of Fuel Cell Procurements, http://www.dodig.mil/Audit/Audit2/94-001.pdf.

KEYWORDS: Fuel Cell Bladders, Reverse Engineering, CAD, Dimensional Scan

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AF141-210 TITLE: Economic Alternative to Wc-Co HVOF Composition for ID Applications for Landing Gear

KEY TECHNOLOGY AREA(S): Air Platforms

OBJECTIVE: Develop economic alternatives to High Velocity Oxygen Fuel (HVOF) spray powder compositions for component bores to replace expensive Tungsten-Carbide-Cobalt (Wc-Co) powders currently used.

DESCRIPTION: Currently, the United States Air Force (USAF) Landing Gear community is implementing Electrolytic Hard Chrome Plate (EHC) replacement for line of sight applications utilizing High Velocity Oxygen Fuel (HVOF) technology. The chemical formulations chosen for this application are Tungsten Carbide-Cobalt (Wc-Co) and Tungsten Carbide-Cobalt-Chrome (Wc-Co-Cr). There are multiple benefits with utilizing this powder chemistry such as superior wear resistance and corrosion protection, however due to its high hardness, grinding and finishing processes are more difficult for HVOF versus EHC. Since Wc-Co and Wc-Co-Cr HVOF coating formulations were developed for Outer Diameter (OD) use and are quite costly, the need exists for more economic alternatives suitable for the less demanding Inner Diameter (ID) applications.

Typical application for landing gear will be component bores from 3 to 5 inches in diameter with the ability to spray deep bores, approximately 18 to 48 inches. Landing gear substrates include 4340 and 300M High Strength Steel (HSS). Testing to be performed includes seal compatibility (Acrylonitrile-Butadiene Elastomer), hydraulic fluid compatibility (both Petroleum and Synthetic Hydrocarbon based), hydraulic pressure (100-3000 psi) and nitrogen sealing ability (10-3000 psi). Since adhesion may be an issue for ID application, with dust and debris contamination in the spray environment, spallation must be tested. In addition, grinding in component bores is quite difficult especially with high hardness coatings. Grinding and or machining processes to achieve the requisite finish requirements for sealing is needed. Corrosion testing will also be required.

Additionally, using HVOF technology is not a hard and fast requirement. Other thermal spray technologies, such as Plasma, which is currently being used in industry and has the potential to be modified (if required or needed) for ID Landing Gear applications is acceptable and will be evaluated with the same scrutiny as HVOF applied coatings. The ability to apply other than EHC coatings to non-line of sight Landing Gear applications will greatly increase the Air Force’s, other Department of Defense (DoD) and commercial entities ability to comply to the mandate of reducing Hexavalent Chrome Emissions as well as the new Occupational Safety and Health Administration (OSHA) standards.

PHASE I: Conduct initial testing on feasibility of powders to replace the current Wc-Co compositions, meeting same performance baselines. Perform initial corrosion testing. Perform seal compatibility testing and spallation. Down select to 2 powder compositions.

PHASE II: Conduct extended testing of Phase I down selected candidates. Perform extended corrosion testing if required. Establish grinding process parameters and establish manufacturing readiness.

PHASE III DUAL USE APPLICATIONS: Implement successful candidates from Phase II. Industry and other DoD Services may also implement a successful substitute.

REFERENCES:

1. TO 4S1-1-182.

2. Dwg 200310641.

3. Dwg 200310642.

KEYWORDS: HVOF, Wc-Co, ID Application

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AF141-211 TITLE: Enhanced Fuel Cells From Wastewater Treatment (Bacteria Generated System) as a Renewable Energy Source

KEY TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Develop and design an innovative fuel-cell technology that will allow generation of electricity from access to bacteria such that it can offset wastewater treatment plant operational costs associated with Military facility/utility operations.

DESCRIPTION: Fuel Cells are promising new energy technology that focuses on new and innovative approaches in which electrochemical/chemical reactions release electricity (electrons) and heat, and a byproduct which is only water. In waste water system, bacteria growth naturally generates electrons as they breakdown organic materials. A microbial fuel cell uses a chemical reaction inside bacteria as the source of its electrons. Since a fuel cell concept already exists that powers the electric grid, a bacteria powering the fuel cell will in turn power the electric grid. Research efforts are required to maximize this concept to make fuel cell energy output more efficient. By accomplishing this task, wastewater treatment processes optimized for fuel cell technology advancements will prove to be a renewable energy technology that will be chartered for military as well as applications.

PHASE I: Demonstrate the feasibility of a prototype fuel cell technology focused on wastewater treatment products and processes that employ bacteria as a source of electron produced naturally as they breakdown organic materials captured in the composition of the wastewater. The system should support real-time characteristics of wastewater and/or industrial wastewater systems suitable for military sites.

PHASE II: Provide a prototype system that demonstrates fuel cell capabilities to generate wattage based on microbial fuel cell theoretical principles, emphasizing chemical reactions that releases electricity and heat energy and produces only water as a by-product. The system design should be expandable to eventually generate enough power to supply the waste water facility itself and eventually feed into the grid itself.

PHASE III DUAL USE APPLICATIONS: Integrate the prototype concepts that are enhanced for acquiring electricity generation that will be applied to the electric grid, thereby realistically recovering enough energy to operate a sizeable wastewater treatment facility.

REFERENCES:

1. Thomas A Clarke, Gaye White, Julea N Butt, David J Richardson, Zhri Shi, Liang Shi, Zheming Wang, Alice C Dohnalkova, Matthew J Marshall, James K Fredrickson and John M Zachara. Rapid electron exchange between surface-exposed bacterial cytochromes and Fe(III) minerals. Proceedings of the National Academy of Sciences, March 25, 2013.

2. Allison M. Speers, Gemma Reguera. Consolidated Bioprocessing of AFEX-Pretreated Corn Stover to Ethanol and Hydrogen in a Microbial Electrolysis Cell. Environmental Science & Technology, 2012; 120628130731000 DOI: 10.1021/es3008497.

KEYWORDS: Microbial Fuel Cells, Wastewater Treatment Processes, Bacteria

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AF141-212 TITLE: Environmentally Friendly Stripping of Low Hydrogen Embrittlement (LHE) Chromium Plate

KEY TECHNOLOGY AREA(S): Air Platforms

OBJECTIVE: Develop Low Hydrogen Embrittlement (LHE) chromium plate stripping method for landing gear eliminating the liberation of hexavalent chrome in the stripping process.

DESCRIPTION: While the current state-of-the-art is changing for landing gear applications, the use of hexavalent chromium (Cr+6) as a wear and/or corrosion preventative surface is still widespread. Current stripping processes for low Hydrogen embrittlement (LHE) Chromium plate can liberate levels of Cr+6 in excess of established OSHA PELs. High Velocity Oxygen Fuel (HVOF) coatings are being introduced, but removal of legacy chrome plated components will be occurring for some time.

Stripping methods that prevent liberation of Cr+6 are desired. Mechanical strip processes could alternately be considered but must consider substrate safety/compatibility (e.g. grinding burns, substrate pitting and degradation). Aqueous stripping processes must consider safety/material compatibility in terms of Hydrogen Embrittlement (HE) on High Strength Steel (HSS) substrates such as 300M and 4340M. All stripping processes must consider material compatibility (fatigue, material removal) and may also require reductive immobilization of Cr+6 from waste products. Replacement processes should be economically viable and preferentially abiotic, with the objective of causing no impacts to labor and processing time in the maintenance cycle.

Substantial research into environmental Cr+6 clean-up and immobilization efforts has been performed, with primary application to soils chemistry. These methods primarily focus on conversion of Cr+6 to Cr+3 through reduction of Cr+6 contaminants by electron-donating compounds and bio-stimulaters.

Bio-stimulaters (e.g. Hydrogen-Release Compound [HRC]) are polylactates that encourage microbial fermentation and a rich, steady supply of Hydrogen as electron donors in the natural conversion of Cr+6 to Cr+3. Abiotic compounds (e.g. Metals Remediation Compound [MRC], Iron Humate, Oxihumolite, Sodium Bisulfite, Iron Oxides, etc.) react directly with Cr+6 in the waste stream, creating a reductive environment for chemical conversion of Cr+6 to Cr+3, which then either precipitates out of solution as solid trivalent chromium hydroxide or binds strongly to iron-oxides in the sorbents or humic acid matrices. Strong binding between Cr+3 and sorbents reduces the likelihood of subsequent liberation into the environment. Abiotic compounds tend to encourage faster reduction and immobilization of Cr+6 and can frequently work at “natural” pH levels (~ 3.9 – 7 pH).

Other methods of reduction of Cr+6 involve eco-friendly stripping methods utilizing acid peroxide solutions to chemically strip Cr+6 from the substrate, then filtering the chromium metal “sheets,” from solution and using electrolytic methods to recover Cu2+ and Ni2+ for reuse. The chromium “sheets” can then be reused, disposed of, or converted to Cr+3 per methods described above. One example of this process can be found in Patent EP1591545B1. The feasibility of these example processes are unknown for landing gear overhaul applications.

PHASE I: Conduct process and material feasibility/safety testing for landing gear applications in the Description of eco-friendly Cr+6 chemical, mechanical, and aqueous stripping, reduction, and immobilization methods/compounds. Downselect to one or two candidates. Provide business case analyses, data, reports, to support feasibility/safety/economic/materials compatibility with landing gear HSS to USAF.

PHASE II: Conduct extended compatibility testing of Phase I downselected candidates, demonstrating compatibility with HSS for fatigue, strength, HE, and corrosion and safe, economic Cr+3 disposal; scale for production; perform prototype processing on various landing gear components with complex geometries within USAF facilities constraints; perform manufacturing readiness studies on Phase I methods. Provide reports/data supporing HSS feasibility/compatibility. Downselect to a single method as appropriate.

PHASE III DUAL USE APPLICATIONS: Implement full scale Phase II method production at USAF Landing Gear Overhaul facility, including all technical data & technical orders for processes, fixture designs and prototypes, recovery and disposal methods, waste stream management and process implementation plans. Ensure seamless transition.

REFERENCES:
1. TO 4S-1-182.

2. TO 1-1-8.

KEYWORDS: Landing Gear, Chrome Plate Strip, Hexavalent Chrome

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AF141-213 TITLE: Method for Evaluating Candidates for Additive Manufacturing (AM) Processes

KEY TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Investigate, determine, and recommend a method to evaluate legacy components which are candidates for Additive Manufacturing (AM) process(es).

DESCRIPTION: With the USAF facing challenges of aging systems, reduced budgets, and increasingly complex supply chains and diminishing industrial base, the need to develop cost-reduction and alternative manufacturing process driven programs now more important than ever. The diminishing industrial base creates a list of hard-to-source components/parts across maintenance organizations that continue to grow, adding workload pressures and backlog within the local alternate sourcing program offices. Besides identifying alternate sources for the same or similar part, the sourcing office is often tasked with identifying alternate manufacturing processes and materials to reduce cost, improve product efficiency through government-contractor developed initiatives. Here in lies the opportunity to leverage the emerging manufacturing process, namely Additive Manufacturing (AM), and combined with part redesign has a positive repercussion on cost saving. One current challenge lies in understanding what legacy components are even viable candidates given the capabilities of the AM technologies and the emerging industrial base. To fully exploit the inherent benefits of additive manufacturing, the responsible configuration design engineer must first identify candidate components/assemblies and then re-engineer the necessary configuration and manufacturing processes required in using AM processes and material configurations. AM does not have the geometric constraints of traditional manufacturing processes, and this absence of geometric constraints allows focusing redesign efforts on part functionality and assembly. Assembling processes and costs can be reduced by rationalizing part count and fabricating devices in their assembled state. The challenge lies in an understanding amongst the sustainment engineers in how to think beyond conventional processes boundaries/constraints and exploit the capabilities of the available AM technologies, equipment, and materials. Conventional redesign parameter examples are component geometry characteristics, dimensional tolerances, shape volume, surface finish, material requirements, loading and cycle conditions, and cost.

The goal of this research effort is to help establish the viability of an AM benchmark and guidelines for sustainment engineers to apply in identification of candidate parts when considering whether AM is a viable and economical alternative to conventional manufacturing methods for legacy components. The methodology would advise on the most promising and efficient AM process, based on Form, Fit, and Function. How performance testing could be waived due to current AM powder material processing already meeting current acceptable specifications should be a very critical parameter.

PHASE I: Research a methodology approach to provide AM benchmark and guidelines on subset of AM technologies/capabilities addressing the above goal. Provide concept demonstration with several AFSC example parts thru the methodology. Examples should show both good and poor candidates for AM success. Concept should include parts requiring different AM processes and materials.

PHASE II: With the success of demonstrated concept in Phase I, continue with expanding the provided methodology with additional AM technologies and processes. Additional AFSC part examples will be demonstrated and validated thru the process. Guidelines should also provide what testing may be necessary or could be waived to satisfy re-engineering requirements.

PHASE III DUAL USE APPLICATIONS: With the success of Phase II validations the transition to high confidence rating for engineering implementation would be performed and have potential for AM and OEM partnerships within AFSC Complexes.

REFERENCES:
1. D. Bourell et al., "Roadmap for Additive Manufacturing: Identifying the Future of Freeform Processing," Proceedings of the RAM Workshop, March 2009.

2. Chua, C. K., Leong, K. F., & Lim, C. S., "Rapid Prototyping: Principles and Applications (2nd ed)," World Scientific Publishing, 2003.

3. Wohlers, T.," Wohlers Report 2012: Additive Manufacturing and 3D Printing, State of the Industry," Wohlers Associates, 2012.

4. Gibson, I., Rosen, D. W., and Stucker, B., Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing, New York, Springer, 2010.

KEYWORDS: Additive Manufacturing, laser sintering, near net shape, 3-D CAD, Maintenance Repair & Overhaul

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AF141-214 TITLE: Beyond Fault Diagnosis and Failure Prognosis Fault Tolerant Control of Aerospace Systems

KEY TECHNOLOGY AREA(S): Information Systems Technology

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors

are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Development of a rigorous health management approach to critical aircraft systems that combines effectively in real-time concepts from Prognostics and Health Management (PHM) and fault-tolerant or reconfigurable control areas.

DESCRIPTION: The Air Force and DoD in general are actively seeking and pursuing the development and utility of new technologies to improve the safety and reliability of critical military assets. Aircraft and other complex systems are subjected to fault/failure modes that may compromise the successful completion of military missions or result in loss of life and/or asset. Past R&D efforts for aircraft safety, reliability and sustainability have focused on the development of on-board sensing strategies, fault diagnosis and failure prognosis algorithms aimed to warn the operator or maintainer of incipient failures. This research has produced significant outcomes with health and usage monitoring systems installed on multiple aircraft/rotorcraft reporting on the health status of their critical components/systems.

New and innovative technologies are needed that build upon and complement PHM methods while providing an added value to the warfighter in terms of improved vehicle autonomy. Consider, for example, a typical mission scenario where an aircraft is flying over enemy territory and is subjected to severe fault conditions. Can the vehicle return safely to the base without experiencing a catastrophic failure? Is it possible that failure prognostic information may assist the reconfiguration of the vehicle’s available control authority so that its remaining useful life could be extended by trading off performance for useful life and allowing the aircraft to land at a safe destination? This topic addresses these important concerns and seeks the development of fault tolerant control methodologies that will take advantage of prognostic information and safeguard the integrity of the asset. The ultimate goal is the design and operation of high-confidence systems that deliver capability as designed. To achieve this goal, the emphasis needs to expand beyond the notion of reliability and prognostics and focus on system integrity management.

Integrity management is viewed in this topic as maintenance of the operational response of high-valued assets in the presence of adverse internal (faults/failures) events. System/component failures and malfunctions are recognized as contributing factors to aircraft loss-of-control in flight. Despite the growing demand for improved reliability, safety and availability of dynamic systems, little work has been published discussing the specific role of prognosis in trolled systems. It is anticipated that the contractor will exploit available or new prognostic routines, i.e. real-time estimates of the Remaining Useful Life (RUL) of failing components in order to reconfigure the available control authority by trading off system performance with control activity. The enabling technologies may take advantage of optimization methods in combination with control algorithms such as Model Predictive Control.

PHASE I: The contractor will conceptualize a framework that exploits on-line prognostic information to trade off system performance for RUL in a control reconfiguration or fault-tolerant control scheme. The emphasis is on the control aspects that will enable such a trade-off to be accomplished resulting in longer vehicle life and completing successfully a designated mission.

PHASE II: Develop fully and validate the modules of the fault-tolerant control architecture with actual aircraft data or available aircraft components in a laboratory environment; the required data for system validation purposes will be provided by the project technical point of contact. The contractor is expected to produce a “product” consisting of software modules for failure prognosis and control reconfiguration that may be applicable to a variety of military and industrial systems/processes.

PHASE III DUAL USE APPLICATIONS: It is anticipated that prognostics enhanced fault tolerant control will improve initially the autonomy, reliability and survivability of military aircraft. Performance and effectiveness of the integrated modules must be demonstrated and compared to other methods.

REFERENCES:
1. Orchard, M., et al., “Advances in uncertainty representation and management for particle filtering applied to prognostics.” Denver, CO: s.n., 2008. International Conference on Prognostics and Health Management.

2. Vachtsevanos, G., Lewis, F., Roemer, M., Hess, A. and Wu, B., "Intelligent Fault Diagnosis and Prognosis for Engineering Systems," John Wiley & Sons, Inc. 2006.

3. D. Brown, G. Georgoulas, B. Bole, H.L. Pei, M. Orchard, L. Tang, B. Saha, A. Saxena, K. Goebel, and G. Vachtsevanos, "Prognostics enhanced reconfigurable control of electro-mechanical actuators" in International Conference on Prognostics and Health Management (PHM), October 2009.

KEYWORDS: Fault tolerance, prognostics, safety, survivability

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AF141-215 TITLE: Corrosion- Preventative, Super-hydrophobic Coatings for Landing Gear

KEY TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Development of ultra water-repellent compounds for application to landing gear in corrosion-prone environments, providing an additional level of corrosion protection for components exposed to difficult service environments.

DESCRIPTION: Landing gear components experience service in extreme environments, and often utilize materials that are prone to corrosion. As such, corrosion prevention is critical in ensuring the safety and reliability of USAF landing gear. Currently, USAF landing gear corrosion prevention comprises one or more of the following, based on the function of the surface: sacrificial platings (cadmium, LHE Zn-Ni), barrier platings (chromium, HVOF, nickel, anodize, etc.), and primer/paint application. However, these defenses can be compromised or can be inadequate for the service conditions to which they are subjected, and as a result USAF landing gear components continue to experience corrosion. Accordingly, the USAF is interested in exploring additional means of corrosion protection. Super-hydrophobic coatings (SHC's) are one such possibility, and are the intended subject of this project.

Application of super-hydrophobic coatings on landing gear could potentially be accomplished in a number of ways, such as: incorporation into paint, incorporation into existing plating processes, or direct application of the super-hydrophobic coating (either to base metal prior to other coating/finishing processes, or at some point along the coating/finishing process, or after all other coating/finishing process have been completed). Each application process may have strengths and weaknesses associated with it, and it may be that more than one application process is needed. For example, incorporating super-hydrophobic materials into paint would have the advantage that no additional processing steps would be required – landing gear could be painted as normal, and as a result the majority of the external surfaces would become super-hydrophobic. However, the disadvantage of this approach is that not all surfaces that are at risk of corrosion are painted - for example, threads on outer cylinders are particularly prone to corrosion, and would not be protected by a paint application. This would perhaps lead to the conclusion that a new application process is needed, but the economics of adding a new process to the depot overhaul and new manufacturing requirements must be considered. Accordingly, a complete solution for super-hydrophobic coatings may need to consider multiple application processes, which would then be selectively applied based on the economic and engineering requirements of the parts to be coated.

Because of the critical nature of landing gear and the sensitivity of many of the materials used in landing gear, compatibility of landing gear materials and any super-hydrophobic material that would potentially be used in a landing gear application must be ensured. So in addition to the corrosion testing that will be required to demonstrate a super-hydrophobic material provides the desired benefit, testing will also be required to ensure the super-hydrophobic coating does not have any unintended consequences. This type of testing includes hydrogen embrittlement testing and fatigue debit testing. Additionally, testing will be needed to demonstrate the practicality of the proposed coating, answering questions such as: How quickly can the coating be applied? How uniformly or consistently can it be applied? How well does it stay on? How does it affect other coatings or paints used on the same part? How can it be removed? For threaded components, how is the torque-tension relationship affected? What are the environmental and health ramifications of the coating, or the processes used to apply and remove it?

PHASE I: Determine application methods for super-hydrophobic coating and conduct preliminary BCA to determine costs for implementation; BCA should include an ROI calculation that compares the anticipated savings to the expected costs. Conduct feasibility testing of super-hydrophobic compound candidates, to include corrosion testing and hydrogen embrittlement testing. Down-select to one or two candidates.

PHASE II: Optimize application/removal of SHC's. Perform fatigue debit testing on representative specimens. Expand corrosion testing to additional materials and coating combinations. Conduct torque-tension testing and corrosion testing to determine applicability to threaded applications. Conduct wear and/or FOD resistance testing to determine survivability. Downselect to final super-hydrophobic coating. Prepare specification to enable the procurement of parts coated with the SHC's. Refine BCA/ROI.

PHASE III DUAL USE APPLICATIONS: Implement successful candidates from Phase II. A successful product may be adopted by all DOD and industry.

REFERENCES:
1. TO 4S-1-182.

2. TO 1-1-8.

KEYWORDS: Super-Hydrophobic, Corrosion Protection

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AF141-222 TITLE: Hot Surface Ignition Apparatus for Aviation Fuels

KEY TECHNOLOGY AREA(S): Air Platforms

OBJECTIVE: Develop and demonstrate hot surface ignition test apparatus capable of controlling all thermal conditions necessary for an accurate evaluation of aviation fluid ignition properties.

DESCRIPTION: Fire protection for military aircraft has been the focus of continuing research for many years. With the Montreal Agreement firmly in place (and the production ban of halogenated fire suppressants), the ability to effectively suppress aircraft fires is of great concern. As a result there is a renewed interest and urgent need to understand fires caused by hot surface ignition (HSI). Unfortunately, much of the published work on HSI was conducted by the Air Force in the 1970s and 1980s on aviation fuels and flammable fluids that were less susceptible to ignition. The general approach of these early studies was to experimentally evaluate a large number of conditions so as to find the most optimum conditions for hot surface ignition of various aviation liquids. As a result, the test conditions tended to be complex, involving irregular hot surface geometries, fluid sprays, fuel drips or streams, varying airflow over the target surface, and in some cases, upstream obstacles in the airflow generating stagnation or recirculation zones near the hot surface. Large variations in the minimum HSI temperature (MHSIT) were reported for the same flammable fluid. Operational assumptions that a hot surface fire would not occur often proved incorrect.

This lack of agreement in MHSIT results from misunderstanding the ignition process and the flow phenomena involved. The current SBIR topic seeks to develop HSI apparatus that is capable of providing a fundamental understanding of hot surface ignition phenomena, and be able to simultaneously produce reliable MHSIT data on aviation fuels. This standalone HSI apparatus must be able to control all necessary fluid thermal conditions to accurately evaluate the probability of ignition of aviation fuels on flat horizontal, flat inclined, and curved surfaces. Thermal conditions of the hot surface must be uniform within +/-10 degrees Celsius with regulation from 350 C to 700 C. Thermal conditions of the flammable fluid must be uniform within +/-5 degrees Celsius with regulation from

0 to 100 degrees Celsius. Thermal conditions of the surrounding test environment must be uniformly controlled and adjustable for airflow and turbulence. Thermal conditions must be documented prior to injection of flammable fluids onto the hot surface. The apparatus must be able to control the fuel flow rate and the method of fuel introduction (i.e., drops, stream or spray). The final HSI apparatus must be validated using well documented fuels for comparison with published data. The apparatus must be suitable for evaluation of legacy fuels, alternative fuels, and hydraulic fluids used within aviation. All output data must be available for development of vulnerability models for both legacy and future aircraft systems.

PHASE I: Design a reliable hot surface ignition apparatus capable of accurately controlling all necessary fluid thermal conditions. As part of the design process a model will be also be developed that can account for variations in temperature, pressure, and airflow, to a sufficient level to enable a better understanding of hot surface ignition, and the impact of surrounding turbulence on ignition.

PHASE II: Fabricate the HSI test apparatus and experimentally document steady fluid thermal fields under different turbulence conditions in the absence of flammable fluids and fire. Compare to the model developed in Phase I and adjust the model accordingly. Test and evaluate HSI properties of a baseline reference fuel, JP-8, and an alternative aviation fuel under controlled conditions. Publish MHSIT results openly for development of vulnerability models for both legacy and future aircraft systems.

PHASE III DUAL USE APPLICATIONS: Commercialize the hot surface ignition apparatus for evaluation of all legacy and future aircraft system flammable fluids for improvements to operational risk assessments.

REFERENCES:
1. J. D. Colwell and A. Reza, "Hot Surface Ignition of Automotive and Aviations Fluids," Fire Technology, no. 41, pp. 105-123, 2005.

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KEYWORDS: Hot Surface Ignition, Ignition, Fuel, Fire, Test, Model

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AF141-223 TITLE: Aircraft Wheel-Tire Dynamic Interface Pressure

KEY TECHNOLOGY AREA(S): Air Platforms

OBJECTIVE: Develop measurement system, with minimal interference (i.e., nano-tech films), for high-load regimes capable of continuous measurement of normal and shear forces along the wheel-tire interface with angular position of a quasi-static rolling tire.

DESCRIPTION: In military aircraft tires, the wheel-tire interface (bead-seat) region is of particular interest since the generated ground forces terminate into the load-bearing “bead-seat” contact area. Thus, the forces generated in both the tire and wheel interface region is of interest. The ability to capture and characterize contact stress behavior at the wheel-tire interface contract region, at a given angular position, may support performance/service life predictions and maybe applicable to enhancing engineering analysis to include: contract load distributions, tire worn limiting conditions, rim slip, wheel fracture indications or roll life, etc.

Additionally, this new measurement system will improve systems performance and reliability by facilitating design optimization of landing gear components. Current laboratory tire test technology, employed by the 96th Test Group’s Landing Gear Test Facility (LGTF), can apply a vertical force up to 75,000 lbs with 30,000 lb side load and brake torque of 240,000 in-lbs to include combined camber (±10 degrees) and yaw (±20 degrees) for a slow rolling tire test (1 inch/second). Existing measurement methods of the contact pressure at the wheel-tire interface are limited to only capturing the normal pressure at this interface. Therefore, a new measurement technology is required to obtain both normal and shear forces at this interface contact region.

The new measurement system should be designed to provide real-time, continuous measurement of contact pressure variations of both the normal and shear forces at the wheel-tire interface of a quasi-static (i.e., slow rolling, ~ 1 inch/second under load) rolling tire assembly. To minimize error and improve the accuracy and fidelity of current technology, the measurement system should introduce minimal test article interference (i.e., apply nano-scale thin films). This measurement system must be capable of accurate and precise operation at greater than 150% of the rated tire load and 3,500 psi at the bead-seat. The goal is to continually measure both the normal and shear forces along the bead-seat. However, smaller measurement areas that enable reconstruction of the entire bead-seat contact stress behavior are permissible (i.e., at known angular locations or positions).

No commercially-available system provides these capabilities. Tire bead seat pressure measurement systems have been used in tire testing, but provide discrete measurements and no information on shear. Films that are sensitive to both normal and shear forces have been developed, but have not been commercialized for tire testing.

The Air Force envisions four levels of success in the program:
(1) Phase I demonstration of a system that can provide the measurements described above in the load/size ranges required for aircraft tire testing.
(2) Phase II laboratory Tire Force Machine testing demonstration.
(3) Phase III development of flight-line-based systems.
(4) Phase III commercialization for airline, automotive/truck, and heavy equipment tire testing.

PHASE I: Demonstrate feasibility of measurement system with minimal test article interference to determine variations of contact pressures (normal and shear stresses) along the wheel-tire interface of a quasi-static rolling tire assembly. Explore tradeoffs relating to measurement area, spatial resolution, sensitivity, and dynamic response.

PHASE II: Apply test measurement method to full-scale demonstration on tire force machine that is applicable to aircraft tire loads and operating environment. Demonstrate sensor test repeatability with less than 5% error and automated data acquisition with data import to finite element models. Show capability to correlate tire/wheel load distributions to define worn limiting conditions and ability to support wheel-tire life prediction. Consider as tool for depot flight line evaluations.

PHASE III DUAL USE APPLICATIONS: Military: Improved predictions and flight-line based test system of aircraft tire performance/integrity intervals to reduce flight-line maintenance checks/tire replacement costs. Commercial: A commercial test to provide advantages in tire wear, safety, traction, and fuel economy.

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KEYWORDS: Normal and Shear Contact Interface Pressure, Dynamic Interface Pressure, Bead-Seat, Wheel-Tire Interface, Flight Line, Aircraft, Maintenance Checks, Cost Reduction, Flight Line Inspection, Aircraft tire, Pressure Measurement, Quasi-Static Loading, Tire Sensor, Stress, Normal Stress, Shear Stress, Safety of Flight, Tire Maintenance, Tire Integrity, Reduced Maintenance Cost and Person-hours, Automotive, Truck or Heavy Equipment Tire Testing,

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AF141-224 TITLE: Modeling Fuel Spurt from Impacts on Fuel Tanks

KEY TECHNOLOGY AREA(S): Air Platforms

OBJECTIVE: Develop a fast-running and accurate analysis code that quantifies the fuel spurt due to hydrodynamic ram within a fluid-filled fuel tank.

DESCRIPTION: Hydrodynamic ram (HRAM) refers to the overpressure produced by the impact and high speed motion of a projectile within a fluid-filled fuel tank. The Air Force has studied this phenomenon for over 35 years. During this time, several physics-based and semi-empirical analysis methods were developed and studied. The current state of the art and most recent work has focused on Arbitrary Lagrange Euler and coupled SPH-Lagrange finite element techniques. While these methods have shown promise in modeling the HRAM event, emphasis was on characterizing the overpressure and resulting tank wall damage and not on quantifying fuel spurting out the entrance hole. Furthermore, current versions of these methods require large computer resources and result in long run times.

Tests show that the ability to accurately predict fire ignition in dry bays adjacent to fuel tanks is dependent on accurate fuel spurt predictions. A modeling capability is needed that accurately accounts for fuel spurt due to hydrodynamic ram within a fast-running analysis code. The code must advance the current state of the art to be able to predict fuel spurt timing, volume, and droplet size resulting from a HRAM event where the tank’s parameters (fluid temperature, pressure, volume, dimensions, materials and thicknesses, curvatures, clutter, fluid depth), impactor parameters (type, velocity, impact obliquity, and propensity for tumbling), and impact location (relative to the fuel head and to tank walls) are modeled variables. The code must able to match test data within 10% of spurt timing, volume, and droplet size.

PHASE I: Demonstrate the feasibility of accurately predicting fuel spurts due to hydrodynamic ram within a generic fluid-filled fuel tank. Demonstrate the ability to accurately represent fuel spurt volume and droplet size as a function of time.

PHASE II: Fully develop the simulation tools demonstrated in Phase I and validate the models and tools on a typical fuel tank having internal stiffening structure and clutter components. Fully validate the ability to accurately represent fuel spurt volume and droplet size as a function of time.

PHASE III DUAL USE APPLICATIONS: Commercialize the code for application all commercial and military air, ground, and sea vehicles that have fluid-filled fuel tanks.

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KEYWORDS: Hydrodynamic ram, fuel spurt, modeling and simulation, fire ignition

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AF141-225 TITLE: Advanced Infrared Emitter Array (AIREA)

KEY TECHNOLOGY AREA(S): Weapons

OBJECTIVE: Develop and demonstrate an IR scene projector (IRSP) based on advanced emitter technology that operates in the mid-wave region with high spatial resolution and high radiant intensity output.

DESCRIPTION: Hardware-in-the-Loop (HITL) test and evaluation of advanced precision guided munitions requires the capability to stimulate sensors and seekers under test with synthetic IR imagery via real-time IR scene projection. An IRSP must be capable of displaying realistic scenes at required refresh rates with sufficient resolution, dynamic range, pixel response times, and accurate radiant intensity output to properly stimulate the unit under test (UUT). Historically, HITL testing has relied on IRSPs that utilize resistor array emitter technology to project IR imagery to the UUT. However, resistor array based IRSPs are constrained in radiant intensity output and spatial resolution due to material composition and fabrication limitations. These restrictions leave resistor arrays incapable of projecting high resolution high temperature IR imagery needed to adequately test next-generation sensors and seekers. Advancements in IR seeker and sensor resolution, sensitivity, and field of view are exceeding IR scene projection capabilities. Analogous advancements in IRSP performance are needed for HITL testing of advanced IR sensors and seekers. In particular, a suitable IRSP must provide the capability to project at least 1k by 1k pixel imagery with maximum temperatures up to 3000K at 400Hz or greater. Also, IRSPs must operate in a non-flickering mode.

Recent developments in alternative IR emitter technology may satisfy requirements to test next generation IR sensors and seekers. In particular, IR LED emitter technology has shown promise in emulating IR scenes that will meet future test requirements. These emitters have demonstrated the capability to present mid-wave IR imagery with high temperature emission in a 512 by 512 pixel format using 48µm pixel pitch technology. Although the IR LED emitters have demonstrated the ability to emulate high temperature IR scene elements, they have not yet demonstrated the ability to support higher resolutions. Also, other technologies exist such as vertical cavity surface emitting lasers that may serve as an alternative IRSP for certain applications.

Novel techniques are required to increase spatial resolution of advanced emitter arrays. Investigation and analysis must be performed to identify approaches for fabricating high resolution emitter arrays and determine the feasibility of implementing these approaches. With an increased resolution, it is desired that the proposed high temperature high resolution emitter array designs maintain the well-established footprint of current generation IR arrays of 48µm pixel pitch with formats of 512 by 512 pixels to ensure compatibility of existing optical components in HITL test configurations.

PHASE I: Identify approaches to increase spatial resolution of advanced emitter arrays. Provide an analysis of alternatives that evaluates the feasibility of each approach and identifies the best approach to pursue. Provide a system performance prediction for the chosen approach.

PHASE II: Design, deliver, and demonstrate a prototype emitter array (greater than 1k x 1k).

PHASE III DUAL USE APPLICATIONS: An advanced IRSP would benefit closed-loop HITL and open-loop testing of advanced IR sensors and seekers. Military uses include test & evaluation of PGMs and aircraft protection systems. Commercial uses include testing of fire/security systems, and thermal imagers used for inspection activities.

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KEYWORDS: infrared scene projector, IRSP, infrared emitter array, hardware-in-the-loop

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AF141-226 TITLE: Real Time Static and Dynamic Flight External Loads Analysis

KEY TECHNOLOGY AREA(S): Information Systems Technology

OBJECTIVE: Research and develop analysis techniques and tools to develop a predictive combined static and dynamic external loads tool using non-proprietary physics-based models and existing flight-test data in a real-time environment.

DESCRIPTION: Airframe external loads (both static and dynamic loads) are dependent on a number of different parameters. For example, horizontal tail loads (bending moment, torsion, shear) may be dependent on Mach number, dynamic pressure, normal load factor (Nz), angle of attack, horizontal tail position, trailing edge flap position, control surface rates, as well as structural dynamics, surface shock waves, etc. In a real-time flight-test monitoring environment, it is critical to be able to accurately and quickly analyze measured external loads to determine what parameters are primarily driving the loads, why there are differences between measured and predicted loads, what is causing the differences in predicted loads, and whether or not the next point in the test point series should be attempted (given a set of expected input parameters). The intent of this topic is to develop a real-time tool that can be used to analyze flight-test data and extrapolate external loads trends within the subsonic, transonic, and supersonic flight regimes.

As a result of contractual constraints, the aircraft structural and aerodynamic models that are developed by the prime contractors are not typically available to the Air Force. Therefore, the tool should be able to incorporate all available sources of information (to potentially include reduced order aerodynamic and/or structural models), but should only require sources of data that would be expected to be available to the Air Force Test Center (AFTC) (analytically predicted component loads for a given set of conditions, allowable load envelopes, and flight test measured data).

The tool should also be able to be integrated into the AFTC real-time control room environment, and should be able to utilize all previously acquired flight-test data to project expected loads for test points yet to be flown given a set of input parameters.

PHASE I: Research in this phase should focus on development of analysis methodology, analysis of alternatives, and predictive techniques, concept of operation, and any analysis needed to demonstrate readiness for Phase II.

PHASE II: Research in this phase should include development of the tool and incorporation into real-time flight-test environment at Edwards Air Force Base, CA.

PHASE III DUAL USE APPLICATIONS: This is an enabling technology that, if successful, will provide improved predictive and flight-test analysis capabilities leading to safer and more efficient loads envelope expansion. If successfully developed, this tool should also have broader use within the commercial flight test community.

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KEYWORDS: loads, flight test

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AF141-227 TITLE: Rule-Based XML Validation for T&E (RuBX)

KEY TECHNOLOGY AREA(S): Information Systems Technology

OBJECTIVE: Develop methods for capturing semantic rules of Test & Evaluation metadata and automate validation of related XML instances.

DESCRIPTION: The use of the eXtensible Markup Language (XML) to define instrumentation metadata for test setup in Test & Evaluation (T&E) is growing rapidly. In particular, the IRIG 106 Telemetry Standard [1] has recently incorporated a translation of the Telemetry Attributes Standard (TMATS) into XML and has added the XML-based Instrumentation Hardware Abstraction Language (IHAL) [2]. Further, the intent is to incorporate the integrated Network Enhanced Telemetry (iNET) Metadata Description Language (MDL) into IRIG 106 in the near future. It is likely that other existing XML-based standards will be used in conjunction with these standards and that new XML-based structures will be developed in the years or decades to come.

The XML standard itself primarily defines syntax, although it also captures some very simple conditions, such as data typing. However, specific instances of XML used in testing must also follow a variety of semantic rules in order to be valid. A simple example of this is that the value of one parameter (say, primary gain) may affect the allowable values of another parameter (say, secondary gain). As the complexity of a T&E instrumentation system increases, the complexity of the rules and difficulty of validation increases as well. In particular, the iNET program will greatly enhance the ability to have multi-vendor systems and a complete XML instance may be created by piecing together segments of XML from different vendors. Estimates for a complete XML instance of a large data system are on the order of a million lines of XML. This requires a system-level validation that cannot be accomplished manually or by the individual vendors. For example, there may be timing constraints imposed by one vendor's devices that can affect the timing of other vendor's devices. In the extreme case, there may be conflicts between vendor's setups that must be deconflicted.

The validation process thus has several levels. First, the rules themselves must be captured, both at an individual device (or vendor) level and at a system level. Second, these rules must be applied against specific XML instances. Third, any conflicts must be identified. If automated approaches to deconfliction can be developed, then there is the potential for some level of automated optimization of the overall setup as well.

As described in [3], this is part of a larger vision to provide automated instrumentation support that allows test engineers to focus on requirements and analysis. The overall problem is a constraint satisfaction problem [4] as described in [5]. The basic mechanisms of automating rule-based validation are being developed in efforts such as The Rule Markup Initiative [6][7] and approaches to optimization include Multi-Constraint Optimization techniques [8]. Part of this effort would be to evaluate what standards and efforts are useful or need to be interfaced with.

PHASE I: Research and develop structures that define instrumentation setup rules for XML-based T&E metadata. Establish theoretical foundations for capturing these rules, for using these rules to automate validation of XML, and to deconflict and optimize multi-vendor instrumentation test system setups.

PHASE II: Refine and expand the rule structures and the mechanisms for capturing the rules developed in Phase I. Work towards standardizing these structures and the non-software based mechanisms (as a non-proprietary standard). Develop software to automate the validation process and, to the extent possible, the deconfliction and optimization processes.

PHASE III DUAL USE APPLICATIONS: Applicable to systems that use instrumentation to collect measurement data, i.e., systems going through developmental T&E, including commercial aircraft, automobiles, heavy equipment, as well as areas such as structures monitoring, general manufacturing, and equipment quality assurance processes.

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KEYWORDS: instrumentation configuration, XML, rule-based validation, multi-constraint optimization, metadata, constraint satisfaction problem

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AF141-228 TITLE: Arc jet Test-Article Surface Recession Rate Monitor

KEY TECHNOLOGY AREA(S): Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop and demonstrate a three-dimensional Recession Rate Monitor system for real-time test article surface contour mapping in arc jet facilities.

DESCRIPTION: A three-dimensional (3-D) recession rate monitor system is needed for real-time test article surface contour mapping in the AEDC arc jet facilities. Surface recession is a critical data parameter for testing of heat shield materials since component design hinges largely on material recession performance. The monitoring system must be non-intrusive to the test article. Test article materials are subjected to high-temperature, high-pressure supersonic flows in the AEDC arc jet facilities to evaluate performance and survivability. Arc heater flow fields impinging the test article range in diameter from 2.5 to 60 cm with gas velocities from 1200 to 2500 m/sec and test article surface temperatures from 2000 to 7000 R. Test models vary in shape but are typically wedge or dome shaped and contained within the diameter of the arc heater flow. During wedge testing, the material ablates while the wedge is held in place inside the test rhombus. For nose tip tests, the test article is moved forward axially as it ablates inside the test rhombus. Typical arc heater run durations range from 30 to 1500 seconds with up to 8 test articles inserted per run. The high enthalpy flows generate intense radiating shocks at the interface of the test article. Also, arc heaters produce high levels of mechanical and acoustic vibrations and electromagnetic radiation. Specific levels of radiation and vibration have not been quantified and are dependent on several parameters related to the arc heater operation and test article geometry.

Currently, on-line monitoring provides two-dimensional (2-D) images along the length of the model with emphasis on the position of the nose tip. For wedge testing, the current method for determining recession is to compare pre and post-test measurements. Recession as a function of time can only be obtained by conducting separate tests with progressively increasing exposure times.

Quantitative ablation recession measurements of test article surfaces are essential to define the performance of candidate materials. A real-time surface mapping capability for arc jet models is necessary to evaluate critical ablation performance of advanced high-temperature materials developed for various DoD hypersonic weapon systems. The resulting 3-D surface maps will enable convergence on high-resolution material response computational models which are essential in the design of thermal protection systems with adequate safety margins and manageable weight budgets to enhance vehicle performance and payload. High-resolution ablation computational models will also enable improved aerodynamic modeling for vehicles operating in the hypersonic regime and subjected to ablative shape-change affecting aerodynamics during flight missions. An innovative approach is sought that will provide a real-time 3-D imaging system that meets the high temporal and spatial resolution capability needs. Phase I should provide a comprehensive engineering analysis and trade study for the optimum approach and a laboratory feasibility demonstration for the recommended approach. The Phase II prototype system should provide recession rate monitoring of 10 x 10 x 3 cm test articles with 3 mm spatial resolution and 30 3-D images per second with a stretch goal of 1 mm spatial resolution, 100 frames per second and the possibility of upgrading to 30 x 30 x 3 cm test articles. The prototype should be demonstrated in the AEDC Arc Heater Facilities, or a comparable operational environment.

PHASE I: Develop an innovative concept for recession rate monitoring for test articles in the AEDC arc jet facilities and demonstrate the spatial and temporal resolution for 2-D images.

PHASE II: Develop and demonstrate the final prototype in the AEDC Arc Heater Facilities, or a comparable operational environment.

PHASE III DUAL USE APPLICATIONS: Diagnostic systems would have direct applicability for thermal protection system material development for military hypersonic systems. Commercial applications include arc jet testing for civil space access/reentry such as those currently under development by NASA and its various contractors.

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KEYWORDS: Diagnostics, recession, ablation, hypersonics, optical instrumentation, reentry,

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AF141-229 TITLE: Non-Intrusive, Seedless Global Velocimetry for Large Scale Hypersonic Wind Tunnels

KEY TECHNOLOGY AREA(S): Sensors

OBJECTIVE: Develop and validate a non-intrusive seedless velocity measurement system for instantaneous global velocimetry at high repetition rates in nitrogen-based hypersonic ground test facilities.

DESCRIPTION: Non-intrusive seedless velocity measurements are needed in nitrogen-based hypersonic ground test facilities. Hypersonic T&E facilities provide forces-and-moments and surface measurements required for the validation of computational tools used to extrapolate tunnel data to flight conditions. Although essential to quantify the aero database uncertainties, current measurement capabilities provide a limited understanding of hypersonic flow physics. This understanding is essential to develop the improved computational tools, such as advanced computation fluid dynamics (CFD) codes, needed to reduce the technical risks of new hypersonic systems such as boost glide concepts currently being considered for conventional prompt global strike (CPGS). Improved knowledge of flow physics requires instantaneous measurements of the velocity field, a capability currently not available in hypersonic T&E facilities.

The goal of this effort is to produce and validate a prototype system for high-rate, global velocity measurements that does not require seeding in nitrogen-based hypersonic wind tunnel facilities. The measurement system needs to provide instantaneous velocity measurements over the wide range of conditions achieved in hypersonic wind tunnels. The accuracy must be equal to or better than +/- 10 m/s corresponding to current state of the art [1] over Mach numbers between 0.3 (blunt bodies) and 14 (free stream measurements), velocities between 100 m/s and 2000 m/s, temperatures between 50 K and 1800 K and pressures between 0.1 and 1000 kPa. The system should also be applicable to laminar, transitional and turbulent flows with and without shock waves. A repetition rate of 1 kHz is needed to obtain converged velocity fluctuation statistics in a single wind tunnel run. Intrusive probe-type devices are not suitable because they disturb the flow field. The size of hypersonic T&E facilities renders anything other than local seeding unfeasible based on cost, complexity and safety considerations. With local seeding, measurements in the shock layer (outside the boundary layer) or in the stagnation region are not feasible. Moreover, local seeding can alter the mean flow, introduce unsteady flow disturbances and requires a sufficient running length to diffuse inside the boundary layer [2].

Significant progress has been made in molecular tagging techniques in nitrogen flows, but measurements have only been performed at a low repetition rate in supersonic nozzle flows [3]. Measurement uncertainties have yet to be characterized for canonical hypersonic flows such as oblique shocks, turbulent or laminar boundary layers. The effect of molecular diffusion on the measurement uncertainties in turbulent flows also needs to be assessed [4]. Fundamental laboratory research and development efforts are required in order to develop and demonstrate a robust and accurate, 2-dimensional, high repetition rate measurement system suitable for the testing and evaluation of hypersonic systems.

PHASE I: Demonstrate the feasibility of a 1-dimensional global seedless velocity measurement for canonical turbulent hypersonic flows in a small scale supersonic or hypersonic wind tunnel at a low repetition rate.

PHASE II: Develop a high repetition rate 2-dimensional global seedless velocimetry system and demonstrate the prototype measurements for canonical laminar and turbulent hypersonic flows in a government-furnished hypersonic wind-tunnel environment. The system can be marketed to customers involved in any high-speed wind tunnel testing as most facilities operate with flowfields containing nitrogen.

PHASE III DUAL USE APPLICATIONS: A global seedless velocimetry measurement system is vital to the development of next generation hypersonic vehicles and munitions.

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KEYWORDS: Velocimetry, hypersonic, nitrogen, non-intrusive, seedless

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AF141-230 TITLE: Large Scale Combustion Air Heater Laser Ignition System

KEY TECHNOLOGY AREA(S): Air Platforms

OBJECTIVE: Develop a laser ignition system for the CAH at AEDC burning liquid isobutane in air at pressures between 50 psia and 500 psia. Other systems may also be considered as long as no unsafe gases or liquids such as hydrogen or Triethylaluminum are used.

DESCRIPTION: The Aerodynamic and Propulsion Test Unit (APTU) is used to test advanced supersonic and hypersonic missile systems in a simulated flight environment. The high total pressures and temperatures experienced by these flight system as they fly through the atmosphere is duplicated in APTU by burning isobutane in high pressure air inside the CAH and then expanding the resulting combustion products through a converging / diverging freejet nozzle. In order to initiate the combustion process in the CAH, an ignition system is required that can operate over a wide range of combustion chamber pressures (between 50 psia and 500 psia) and also survive the much higher pressures and temperatures created by the CAH during a test run (up to 2800 psia and 4700 Deg. R). The overall equivalence ratio in the CAH combustion chamber during the ignition sequence can vary from as low as 0.2 to as high as 0.7. At no time is the overall ignition sequence equivalence ratio greater than stoichiometric. The bulk velocity of the air and atomized fuel is on the order of 100 to 150 ft/sec during the ignition sequence, although the flow velocity may be three times as fast since the ignitor penetration in the combustion chamber wall is located approximately five inches downstream of the CAH swirler cups and liquid isobutane fuel injectors. The current CAH ignition system uses two small gaseous hydrogen and air torches with the tips of the torches recessed a small amount in the combustion chamber wall. The use of gaseous hydrogen causes significant safety issues in and around the test cell building, plus the test setup process is procedurally complex. Additionally, the torch system is limited in its operational range due to the torch jet's limited ability to penetrate into the combustion chamber when operating at higher ignition pressures. The majority of the two torches are not embedded into the CAH combustion chamber; rather they are mounted on the outside of the CAH. The part of the system that penetrates into the CAH has to withstand the full operational range of the CAH as described above. The part of the system outside the combustion chamber is exposed to test cell pressures as low as 0.5 psia, although the ignition process generally occurs at around 5 psia in the test cell. A laser-based ignition system is envisioned since it can focus its energy on the order of six inches into the combustion chamber under a wide range of conditions. Laser ignition systems have been experimentally researched for automobile applications, but no commercial products are known to exist. Laser systems typically used at APTU are placed outside the test cell and the beam is routed into the test cell via fiber optic cable. Several locations just outside the test cell are available to site hardware for this system. Alternate types of ignition systems, such as plasma torches or other innovative methods, will also be considered as long as they are meet stated requirements, are technically feasible and don't require unsafe gases or liquids.

PHASE I: Perform a comprehensive evaluation and documentation of the current state-of-the-art of this technology, identifying existing applications of the technology. Provide a rigorous description of the required hardware and software to be employed in developing and demonstrating a working system.

PHASE II: Based on Phase I results, build and demonstrate a prototype laser ignition system using flowing air as the oxidizer and atomized liquid isobutane as the fuel. Prototype system must operate with a combustion chamber pressure over 50 psia. Provide a conceptual design for integrating the system in with the CAH in place of the existing hydrogen / air torches.

PHASE III DUAL USE APPLICATIONS: A commercially viable laser ignition system would have military and commercial applications for a variety of internal combustion and gas turbine engines.

REFERENCES:

1. Garrard, Glenn, “Development of the Combustion Air Heater Ignition Sequence at the Aerodynamic and Propulsion Test Unit,” AIAA 2009-7359, 16th AIAA/DLR/DGLR International Space Planes and Hypersonic Systems and Technologies Conference, October 2009.

2. Bihari, B., Gupta, S. B., Sekar, R. R., Gingrich, J. and Smith, J., “Development of Advanced Laser Ignition System for Stationary Natural Gas Reciprocating Engines,” ICEF2005-1325, ASME-ICE 2005 Fall Technical Conference, Ottawa, Canada, 2005.

3. Gupta, S. B., Sekar, R. R., Klett, G. M., and Ghaffarpour, M., “Ignition Characteristics of Methane-air Mixtures at Elevated Temperatures and Pressures,” SAE 2005-01-2189, SAE Transactions Journal of Fuels and Lubricants.

4. http://www.engineersedge.com/engineering/Engineers_Edge/replacing_the_spark_plug_with_a_laser_igniter_9423.htm.

KEYWORDS: Ignition, laser ignition, combustion, air heater, hypersonic

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AF141-231 TITLE: Alternative Approach to Contact Type Analogue Data Slipring

KEY TECHNOLOGY AREA(S): Air Platforms

OBJECTIVE: Develop an approach for robust and reliable, non-contact, data transmission of up to 300 channels of dynamic and steady-state measurements streaming from instrumentation rotating up to 2048 RPM.

DESCRIPTION: A robust and reliable data transmission technology is needed using non-contact methods for up to 300 channels of dynamic and steady state instrumentation for machinery rotating up to 2048 RPM. The in-field application will be for use on scaled and full scale powered, wind tunnel helicopter test stands. Contact type sliprings are currently used to transmit analog instrumentation signals from the rotating frame down to the stationary frame and ultimately to the data acquisition system. These contact type sliprings are notoriously noisy, require frequent cleaning (causing testing downtime) and have to be specially tuned to very specific RPM ranges of operation. Standard, typical instrumentation data originates at Wheatstone bridges and must be transmitted from the rotating frame to the stationary frame ultimately ending at a custom data acquisition system 61 m from sensor location with no direct line of sight. Wheatstone bridge strain gage measurements are most typical but transmission should be robust to include pressure transducer measurements, thermocouples, RTDs and accelerometers. All 300 channels or rings of the slip ring are identical in terms of ability to handle voltage and resistance requirements. This allows the slipring to be configured in any arrangement. This maximizes the utility of the slipring for different types of gages (i.e. 2 wire or 4 wire gages, common power vs. individual power gages), as well as rerouting problematic gages (i.e. +signal goes out and needs to be sent down over a different ring). For strain gage measurements, a means to provide excitation voltage between 5 and 20 volts must be provisioned. Typical output voltages are on the order of 0 – 20 mV. Additional requirements for strain gage measurements is the ability to auto balance or off set removal of gage drift as well as a precision RCAL function also known as shunt calibration in the range of 0 – 500 Ohms. This RCAL is set by the amplifiers at the data system and does not require any special configuration on part of the slipring. Data sampling must be able to be externally triggered from an azimuth position sensor up to 2048 RPM. Dynamic data rates must be at least 20 kHz. Transmission across the rotating frame must be through non- contact means and must simultaneously sample up to 300 unique channels of data. The prototype system must be less than 1.2 m long and no greater than 0.5 m in diameter. The slipring should be designed to handle vibrations up to 0.2 IPS and operate in a temperature range of 10-100 degrees Celsius.

Challenges associated with this project: The wind tunnel is an acoustically treated steel metal frame. High frequency digital transmissions like telemetry systems have not worked in the past due to high instances of reflection and bounce-back of signals. A telemetry type of system would have to be specifically engineered to work within the test environment of the wind tunnel and anticipate these “electrically noisy” conditions.

A fully functioning system would immediately be useful in the full scale wind tunnel, however the unit could be integrated into any rotating machinery testing application across government or industry. Example production or research industries would include turbines, engines, powerplants, generators, truly any rotating system that requires instrumentation transmission.

PHASE I: Design a transmission scheme meeting the parameters above including wiring diagrams, component identification and manufacturers specifications meeting or exceeding system requirements. Document the final design in a formal report detailing design approach and process and market survey elements.

PHASE II: Build and demonstrate system functionality in a “bench top” arrangement. Document all system changes and operational settings and tweaks that differ from phase I design.

PHASE III DUAL USE APPLICATIONS: System integration with research test rig used for tilt rotor hub and blade system in full scale wind tunnel applications.

REFERENCES:

1. Moog Sliprings: http://www.moog.com/products/slip-rings/.

2. Aerodyn Sliprings: http://www.aerodyneng.com/.

KEYWORDS: data transmission, instrumentation, data system, non-contact, data acquisition

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AF141-232 TITLE: Temperature-Compensated Pressure Sensitive Paint (PSP) for use in Nitrogen Environments of Large-Scale Blowdown Hypersonic Facilities

KEY TECHNOLOGY AREA(S): Sensors

OBJECTIVE: Develop a temperature-compensated, pressure sensitive paint system capable of measuring global surface pressure on test articles in a nitrogen-based, large-scale production hypersonic ground test facility.

DESCRIPTION: A innovative measurement capability is needed for large-scale production hypersonic facilities that will enable high-resolution global surface pressure measurements essential for development and validation of modern computational tools and visualization of complex flow phenomena such as separation and shock-boundary layer interactions. Understanding of complex flow phenomena and advancement of high-fidelity computational tools are critical for development and fielding of future hypersonic systems such as conventional prompt global strike (CPGS) systems. Current measurement technologies of this nature are sensitive to oxygen and therefore limited for use in oxygen wind tunnels. Furthermore, temperature gradients on the surface of the model are created by the high Reynolds number/high Mach number flows in hypersonic test facility and can cause localized temperature errors in many pressure measurement systems. A solution based upon pressure sensitive paint (PSP) technology that is a true pressure sensor (i.e. not an oxygen detector) is envisioned; however, other innovative solutions that meet the needs will be considered.

The global pressure measurement system is required to accurately sense model surface pressure in pure nitrogen over the pressure range from 0.01 psia to 20 psia. If the pressure measurement technology exhibits temperature sensitivity, it must be compensated for a nominal temperature range of 50 deg F to 250 deg F to ensure accurate pressure measurements. Temperature gradients on the model can be as high as 65 deg F per inch; that is the model is not at a uniform temperature. Models are constructed in order to preserve this temperature gradient so that it may be measured by a global temperature measurement already in place. If a PSP coating is proposed that is insulative in nature, higher temperatures will be experienced by the coating. The coating must be able to survive temperatures up to 350 deg F or more depending upon the thermal properties of the coating. The wind tunnel test articles are at a uniform initial temperature (50 to 70 deg F) and pressure (~ 0.02 psia) at the start of every run and are located in the test cell throughout the run (start up and shut down; i.e. not injected). The usable run time, defined as the time with constant flow conditions, over which data must be collected range nominally from 0.25 to 5 seconds. The models may be dynamically pitched through an angle of attack during the usable run time at rates of up to 60 degrees/sec. The response time of the pressure measurement system must be fast enough to measure the pressure changes due to pitching over these short run times. Uncertainty of global pressure measurements should be +/- 2% of measured value.

Paints should work with standard stainless steel wind tunnel test articles and not interfere with the data acquisition of discrete model surface instrumentation such as pressure taps, surface mounted pressure transducers and coaxial thermocouples and internal strain gage balances. The pressure measurement system should be compatible with concurrent Schlieren/Shadowgraph measurements. Coatings should produce useful data for up to 2000 seconds of wind-on time. Coating samples can be tested in the Tunnel 9 facility to assess adhesion and durability. Factors that can reduce lifespan of the coating such as temperature and/or photodegradation can be simulated in a lab setting to assess coating useful life span. Existing temperature-sensitive paint system components such as the 365 nm UV illumination system for paint excitation and EMCCD cameras may be used for this system to increase interoperability between the existing TSP system and a future PSP system. The pressure measurement system should make use of current optical access ports that utilize BK7 glass if possible. Ref [1] gives details of the TSP system currently in use at the AEDC Tunnel 9 facility. Ref [2] reports on a traditional PSP measurement (oxygen based) adapted to a hypersonic wind tunnel while simultaneously making TSP measurements. Note that a specialized wind tunnel model construction using various materials was used to aid these measurements. That is not desirable for this SBIR. Ref. [3] discusses a oxygen-based PSP test which used a temperature sensitive paint coating to correct for temperature changes on the model during the wind tunnel runs.

PHASE I: Demonstrate feasibility of temperature compensated PSP measurements in a nitrogen environment on a stainless steel surface non-intrusive to standard wind tunnel surface instrumentation such as pressure transducers and thermocouples. Generate coating manufacturing and application procedures for use by AEDC personnel.

PHASE II: Develop and deploy the PSP system in a government-furnished large-scale nitrogen-based blowdown hypersonic wind tunnel. Test article and wind tunnel time will be provided by the government. The coating possibly would be a true pressure sensor and could be used for multiple non-wind tunnel measurement applications where oxygen is not present or known, such as combustion or water measurements.

PHASE III DUAL USE APPLICATIONS: A pressure sensitive measurement system that meets these requirements could be useful for multiple testing disciplines as the requirements listed do not prohibit its use in other test facilities or even for other than wind tunnels.

REFERENCES:

1. Kurits, I., Norris, J. D., "Hypersonic Global Heat-Transfer measurements During Continuous Pitch Sweeps at AEDC Tunnel 9", AIAA Paper 2010-4802.

2. Watkins, A.N., Buck, G.M., Leighty, B.D., Lipford, W.E., and Oglesby, D.M., "Using Pressure- and Temperature-Sensitive Paint on the Aftbody of a Capsule Vehicle", AIAA Journal Vol. 47, No. 4, p. 821-829, April 2009.

3. Sellers, M. E., "Demonstration of a Temperature-Compensated Pressure Sensitive Paint on the Orion Launch Abort Vehicle," AIAA Paper 2011-3166.

KEYWORDS: PSP, hypersonic, global surface measurements

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AF141-239 This topic has been removed from the solicitation.

AF141-243 TITLE: Advanced Space Antenna for GPS

KEY TECHNOLOGY AREA(S): Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop an advanced, space antenna with a steerable, formable beam for GPS satellites.

DESCRIPTION: GPS satellites currently use fixed beam L-band antennas to provide hemispherical coverage of the earth. Basically, each signal broadcast has to be strong enough to be received by user equipment even at the far edges of the hemisphere. The current design uses a bank of helical antennas and can provide enough tuning capability to broadcast at a higher power toward the edges of the hemisphere. Using this technique, the received signals can all have roughly the same received power in the center of the hemisphere as they do on the edge of the hemisphere.

GPS support for the military is sometimes compromised by weak signals due to the terrain, active spoofing of the GPS signals, active jamming of the GPS signals, interference from background radiation, etc. With the current, fixed beam, hemispherical broadcast approach, there is no way to increase the GPS signal power to a specific area of interest. There is a need to be able to focus the GPS broadcast on a specific area of interest, steer it to maintain the beam on that area, and provide a minimum of 5 dB higher signal strength for better general reception, overcoming a jammer, etc.

This could be accomplished by steering the beam in the same manner as phased array radar. A phased array antenna is typically constructed from multiple Transmit/Receive (T/R) elements and uses phase shifting to steer the beam

electrically. This could also be accomplished with an array of stacked patch antennas, an array of helix antennas, etc. It is desirable to avoid mechanically steering the beam due to size, weight and power (SWaP) and cost issues. However, a mechanical beam steering system could be considered if it can be shown to have equal or better performance, SWaP, and cost as an electrical beam steering system. Cost goal for this antenna <$1M/m2 when produced in quantity. Careful attention should be paid to reducing each SWaP element by >10% over current antenna, and minimizing electro-magnetic interference (EMI). The proposed antenna should be suitable for use in a MEO space environment including radiation hardening. The radiation-hardness requirements for the electronically steerable antenna are:
Effect: Units: Level:
Total Ionizing Dose rad(Si) 1e6
Single-Event Upset Err/bit-day 1e-10
Single-Event Latchup None
Dose-Rate Upset rads(Si)/s 1e10
Dose-Rate Survivability rads(Si)/s 1e12

Proposals should clearly indicate how the result of the effort would be shown to improve the GPS system's capabilities through a test and validation plan. Testing and validation of risk reduction components of the overall effort in Phase I is encouraged.

Offerors are encouraged to work with PNT system prime contractors to help ensure applicability of their efforts and begin work towards technology transition. Offerors should clearly indicate in their proposals what government furnished property or information are required for effort success. Requests for other-DoD contractor intellectual property will be rejected.

PHASE I: Design and simulate a steerable beam antenna for space-based, L-band GPS applications. The antenna design should focus on high efficiency, low power, and lightweight. A brassboard is desirable for this effort.

PHASE II: The selected company will fabricate and produce a brassboard and space-qualifiable flight prototype antenna for test and evaluation. Phase II efforts should include ensuring compatibility with ICD supporting overall payload and space vehicle reference designs as part of their commercialization effort. ICD will be supplied to Phase I awardees invited to propose for Phase II.

PHASE III DUAL USE APPLICATIONS: The selected company will work with a major GPS contractor to include the results of this effort in a GPS satellite test flight/upgrade.

REFERENCES:
1. Fenn, A. J.; Temme, D.H.; Delaney, W.P.; and Courtney, W.E. "The Development of Phased-Array Radar Technology." 2000. Lincoln Laboratory Journal, Vol 12, No. 2.

2. Varlamos, P.K. and Capsalis. C.N. "Electronic Beam Steering Using Switched Parasitic Smart Antenna Arrays." 2002. Progress In Electromagnetics Research, PIER 36, 101-119.

KEYWORDS: GPS, L-band, Phased Array, Beam Steering, Anti-Jam, ICD, Component Interface Descriptions

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AF141-244 TITLE: Distributed Sensor Management for RSO Detection, Classification and Tracking

KEY TECHNOLOGY AREA(S): Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop innovative sensor management methods and algorithms to enable effective resident space object detection, classification and tracking under challenging communication environments.

DESCRIPTION: Current ground-based radar, telescopes and space-borne space surveillance assets that comprise the space surveillance network can be augmented to provide full characterization of every resident space object (RSO) in orbit from birth-to-death. This would allow persistent space situational awareness from the knowledge of traditional large satellites to picosatellites and orbital debris at Low-Earth-Orbit (LEO), Medium-Earth-Orbit (MEO), and Geosynchronous-Earth-Orbit (GEO) altitudes. Innovative approaches are sought through a combination of new and existing sensing resources with a carefully designed distributed sensor management scheme. Current plans are to augment the radar and optical telescopes in the existing space surveillance network with a 3.5-m Space Surveillance Telescope (SST), the Space Based Space Surveillance (SBSS) system, and the S-band Space Fence system. These will address the detection, classification and tracking of space objects, but determining the object's intent or its potential capabilities will be difficult when sensing resources are limited.

As expected, a distributed sensor management scheme that best utilizes the available sensing resources will improve the capability of RSO detection, classification and tracking. Particularly, new sensor management method and associated algorithms are sought to address the following aspects: i) The goal of sensor management is to learn the global objective function online and efficiently allocate sensing assets in a distributed manner with quantifiable performance gap to the optimal solution (which is computationally prohibitive to obtain); ii) The scheme has to consider maneuver detection and nonlinear orbital state estimation with explicit models of intentional evasive motions; iii) The method has to address how to fuse heterogeneous sensor measurements and improve the existing constellation from the dynamic reconfiguration of sensing assets; iv) The solution should follow open source standard for the software development that can process heterogeneous sensory data; and v) Data sharing and onboard processing to reduce bandwidth requirements are subject to unreliable inter-satellite link (ISL) communications due to high relative angular velocity between space-based sensors and inter-plane ISL shut-offs at certain high latitudes. The proposer should develop sensor management simulation testbed and demonstrate agile sensor scheduling capability in orbital maneuver detection and collision alert.

PHASE I: Develop and demonstrate feasibility of the proposed sensor management method and algorithms with realistic space surveillance scenarios. Model the intent of object's maneuver for accurate early collision alert. Quantify the benefit of dynamic reconfiguration for tracking multiple LEO and GEO objects of various sizes, attributes and maneuver capabilities.

PHASE II: Refine detailed designs for the Phase I sensor management, algorithms, and suitable proof-of-concept. Demonstrate potential and feasibility of the algorithm(s) using simulated data generated by 3 geographically dispersed and cooperative ground and space-based radar and electro-optical sites. Characterize algorithm performance using metrics/trade parameters. Phase II efforts should include ensuring compatibility with JMS component interfaces.

PHASE III DUAL USE APPLICATIONS: Technology should be matured and transitioned to Joint Space Operations Center (JSpOC) and potentially interested commercial and other government agencies (e.g., NASA).

REFERENCES:
1. D. Hall, "Surface Material Characterization from Multi-band Optical Observations," Proceedings of the Advanced Maui Optical and Space Surveillance Technologies Conference, pp. 60-74, 2010.

2. T. Payne, S. Gregory, et al., “Satellite Monitoring, Change Detection, and Characterization Using Non-Resolved Electro-Optical Data From a Small Aperture Telescope,” Proceedings of the Advanced Maui Optical and Space Surveillance Technologies Conference, pp. 450-463, 2007.

3. Y. Bar-Shalom, W.D. Blair, Editors. Multi-Target/Multi-Sensor Tracking: Applications and Advances, Vol. III, Norwood, MA: Artech House, 2000.

4. D. Hall, J. Llinas, An Introduction to Multisensor Data Fusion, Proceedings of the IEEE, Vol. 85(1), 6-23, 1997.

5. A. Hero, D. Castanon, D. Cochran, K. Kastella, Editors. Foundations and Applications of Sensor Management, Springer, 2008.

KEYWORDS: space situational awareness, sensor management, maneuver detection, object tracking and classification, intent estimation and prediction

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AF141-245 TITLE: L-Band Wide Bandwidth High Performance Diplexer, Triplexer, and Quadruplexer

KEY TECHNOLOGY AREA(S): Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop diplexer, triplexer, and quadruplexer for multi-carrier RF combining on Global Positioning System satellites.

DESCRIPTION: As GPS became a ubiquitous global utility, both for civil and military use, the number of digital signals has more than doubled from the original system. A flexible navigation payload is a requirement for the GPS III system, to include digital waveform generation and potentially new signals. To support flexible signal generation, new n-plexers should support wider bandwidths on the GPS carriers, especially for L1 and L2. Additionally, the higher signal powers for modernized GPS has increased the risk of multipaction. Careful consideration is required to ensure sufficient margin to support even higher power requirements in the future.

These devices should accommodate bandwidths up to 45 MHz, while avoiding multipaction for up to 500 Watts and achieving insertion loss of less than 0.5 dB.

Proposals should clearly indicate how the result of the effort would be shown to improve the GPS system's capabilities through a test and validation plan. Testing and validation of risk reduction components of the overall effort in Phase I is encouraged.

Offerors are encouraged to work with PNT system prime contractors to help ensure applicability of their efforts and begin work towards technology transition.

Offerors should clearly indicate in their proposals what government furnished property or information are required for effort success. Requests for other-DoD contractor intellectual property will be rejected.

PHASE I: Develop an innovative concept for new diplexer, triplexer, and quadraplexer designs for GPS L-Band signals.

PHASE II: The effort will design and build a brassboard or prototype for one or more of the designs (diplexer, triplexer, or quadraplexer), for ground test and evaluation. Phase II efforts should include ensuring compatibility with component interface descriptions supporting overall payload and space vehicle reference designs as part of their commercialization effort. Interface descriptions will be supplied to Phase I awardees invited to propose for Phase II.

PHASE III DUAL USE APPLICATIONS: Military application: Successful completion of the space qualification tests and transition to production for inclusion in GPS satellites. Commercial application: Wide Area Augmentation System (WAAS). Commercialization in a Phase III motivates partnerships with GPS system contractors.

REFERENCES:
1. GLOBAL POSITIONING SYSTEM: THEORY AND APPLICATIONS, Vol 1, Bradford W. Parkinson and James J. Spilker, Jr., editors, 119, p. 217, 230-232.

2. Microwave Filter Components, Aeroflex Microelectronic Solutions, March 14, 2011.

3. GPS/IGS Design Analysis Report, Volume 1, Rockwell International, 15 November 1982.

4. GPS IIF and Modernization – Taking the Most Advantage of GPS IIF Flexibility, Peter Fyfe, Kamran Ghassemi, Douglas Thomson, Eric Watts, Institute of Navigation, ION GPS 2001, 11-14 Sep 2001, pp 641-649.

5. ICD-GPS-200G, Global Positioning Systems Directorate, 5 Sep 2012.

KEYWORDS: GPS, Diplexer, Triplexer, Quadraplexer, Signal Combining, Radio Frequency Filter

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AF141-248 TITLE: Improved satellite catalog processing for rapid object characterization

KEY TECHNOLOGY AREA(S): Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop algorithms to enable rapid cataloging and characterization of space objects in support of space situation awareness and orbital safety.

DESCRIPTION: Effective space control and situational awareness require continuous and accurate tracking of space objects with a limited number of sensing platforms. The U.S. Air Force Space Surveillance Network (SSN) is a critical foundation of U.S. space operations. It is a network of sensors scattered across the globe which provide both tracking and identification data on objects in Earth orbits. The SSN provides the information to the Joint Space Operations Center (JSPOC), which has the mission to detect, track, identify, and catalog all man-made objects in Earth orbits. Approximately 500,000 individual observations are collected each day by the SSN. The SSN observations are used to maintain the satellite catalog, predict atmospheric re-entry of space objects, catalog new launches, detect satellite maneuvers, and safeguard important satellites such as the International Space Station. Due to uncertainties in position determination and the inability to track objects continuously the problem of maintaining situational awareness of all space orbiting objects is challenging. On a daily basis, observed objects must be correlated with objects within the space catalog and accurately characterized. Due to orbital decay, maneuvers, and the generation of new objects there is a high degree of uncertainty in the characterization of space objects and a need exists for the timely and accurate cataloging of objects. A number of algorithmic techniques are used to correlate observed objects with catalog objects and provide catalog updates. Due to uncertainties the processing of uncorrelated targets is a time consuming and challenging problem. With the rise of multi-sensor fusion and exploitation techniques an opportunity exists for obtaining improved comprehensive and continuous space domain awareness of activities, systems, and the environment. There is growing demand for the development as well as the verification and validation of the emerging decision support algorithms and systems toward space catalog processing which will lead to enhanced situational awareness. To compound the technical challenges, any uncertainties in sensor models, object identification templates, or object motion models may cause significant degradation in the tracking accuracy of the existing state-of-the-art methods such as Joint Probabilistic Data Association Filter (Joint PDAF), Joint-Belief PDAF, and Interactive Multiple Model PDAF. The focus of this topic solicitation is to address the problem of cataloging and processing of satellite objects. Improved algorithms and methodologies are sought which will improve correlation of observed objects with cataloged objects. Techniques must account for dynamic data cluttering to provide non-standard measurement updates that effectively estimate models of unknown, dynamically evolving data sets, such as background clutter, so that 1) the detection and clutter characteristics for participating space-based sensors can be forecasted and 2) advanced multi-object filtering to detect and tracking of multiple nonstandard objects obscured by unknown, dynamically changing clutter. Key technical challenges for mathematical footings and technology foundations will include constructive methods and efficient analysis that can extract clutters for multi-object filters of detecting and tracking non-standard objects in difficult environments which are obscured by unknown background clutters. Innovative solutions are sought for efficient filtering implementation for both known and object-dependent clutter and unknown probability of detection and effective fusion of local tracks from local object states subject to distributed sensing and tracking situations whereby local trackers may have different models of object dynamics.

PHASE I: Using a representative space catalog and space environment, develop and demonstrate a set of algorithms that would provide rapid correlation of observed objects with cataloged objects. Techniques should demonstrate improvements in uncertainty and demonstrate scalability. Demonstrate a proof-of-concept.

PHASE II: Refine the detailed designs for the Phase I space catalog/environment algorithms and provide a suitable proof-of-concept framework. Phase II efforts should include ensuring compatibility with component interface descriptions supporting Joint Mission System (JMS) reference designs as part of their commercialization effort. Interface descriptions will be supplied to Phase I awardees at Phase II.

PHASE III DUAL USE APPLICATIONS: The target program is the SMC JSpOC Mission Systems (JMS) program. Targeted technologies would be matured through the SMC and AFRL led JMS Testbed effort.

REFERENCES:
1. Theresa Hitchens, "Ante Up on Space Situational Awareness," Space News, Mar. 12, 2007. For the official definition of SSA, see Air Force Doctrine Document (AFDD) 2-2, Space Operations, Nov. 27, 2006, p. 55.

2. E. Nelson Hayes, Trackers of the Skies (Cambridge, Mass.: Howard A. Doyle, 1968), 1-47; W. Patrick McCray, "Amateur Scientists, the International Geophysical Year, and the Ambitions of Fred Whipple," Isis 97:4 (2006):634-58'

3. Brad M. Evans, "The History of The Space Surveillance Network and Its Capabilities," Paper for Space Studies 997, University of North Dakota, Jul. 24, 2003, pp. 5-6.

KEYWORDS: pace catalog, space situational awareness, SPADOC

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AF141-250 TITLE: 64MB+ Radiation-Hardened, Non-Volatile Memory for Space

KEY TECHNOLOGY AREA(S): Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop and commercialize 64MB (min, MB=1,000,000 bytes of memory, 1 byte=8 bits), radhard, nonvolatile memory (RHNVM) for space applications.

DESCRIPTION: The lack of low-cost high-density Radiation-Hardened (RH) Non-Volatile Memory (NVM) continues to be a severely limiting factor in the design of systems for use in space environments. Present solutions rely on inefficient hardening techniques, such as radiation hardening by design (RHBD), which are implemented either in layout or in the application architecture and not in the fabrication process. Many of these solutions are based on redundancy and result in a performance penalty. Moreover, most aerospace applications preclude the use of moving parts, such as the one in a hard disk. Thus, an ultra-high density storage solution is completely lacking. Efforts over the last two decades to develop a practical NVM solution for space have fallen short of the density and performance needs. A radiation-hard NVM that can achieve high density is needed.

Commercial NVMs have greatly increased in density while reducing cost in recent years, creating a gap of more than six orders of magnitude between commercial and RH devices. Universal Serial Bus (USB) drives or Secure Digital Input/Output (SDIO) memory cards have achieved the density of hard drives over just a couple of years. While these commercial devices are not suitable for space applications, some technologies used by these commercial devices are inherently RH and could be used to build a device suitable for space applications. The suitable technologies then need to be developed into high density, space-qualified NVM devices. This call solicits efforts to develop and commercialize high-density high-performance RH NVM technology to serve space markets.

Radhard reqs for RHNVM:
Effect: Units: Level:
Total Ionizing Dose rad(Si) 1e6
Single-Event Upset Err/bit-day 1e-10
Single-Event Latchup None
Dose-Rate Upset rads(Si)/s 1e10
Dose-Rate Survivability rads(Si)/s 1e12

Proposals should clearly indicate how the result of the effort would be shown to improve the GPS system's capabilities through a test and validation plan. Testing and validation of risk reduction components of the overall effort in Phase I is encouraged.

Offerors are encouraged to work with PNT system prime contractors to help ensure applicability of their efforts and begin work towards technology transition.

Offerors should clearly indicate in their proposals what government furnished property or information are required for effort success. Requests for other-DoD contractor intellectual property will be rejected.

PHASE I: Review existing NVM technology literature and evaluate and incorporate (if appropriate) findings to this effort. Based on these results and other available metrics such as device uniformity, endurance, reliability, commercial viability, and design flexibility; complete the design of a NVM using the most promising technology.

PHASE II: The selected company will partner with an appropriate foundry to produce working prototypes that are suitable for space applications, then test and evaluate the prototypes for reliability and radiation hardness. Phase II efforts should include ensuring compatibility with CID supporting overall payload &space vehicle reference designs as part of their commercialization effort. CID will be supplied to Phase I awardees invited to propose for Phase II.

PHASE III DUAL USE APPLICATIONS: The selected company will build and commercialize a RH NVM with a density of at least 64MB for space applications.

REFERENCES:
1. Chua, L. O. "Memristor - The Missing Circuit Element." IEEE Trans. Circuit Theory 1971: 18, 507-19.

2. Clarke, Peter. Dual layer helps ReRAM reach mainstream capacity. 25 02 2013. 15 03 2013 <http://www.eetimes.com/design/memory-design/4407691/ReRAM-storage-capacity-reaches-mainstream-size>.

3. McHale, John. Rad-hard company designs non-volatile memory for megarad environments. 01 06 2009. 17 03 2013 <http://www.militaryaerospace.com/articles/print/volume-20/issue-6/news/news/rad-hard-company-designs-non-volatile-memory-for-megarad-environments.html>.

4. Schindler, C., et al. "Low Current Resistive Switching in Cu-SiO2 Cells." Appl. Phys. Lett. 2008: 92, 122910-122911.

5. Tong, W. M., et al. "Radiation Hardness of TiO2 Memristive Switches." IWWW Trans. Nucl. Sci. 2010: 57, 1640-43.

KEYWORDS: Memristor, non-volatile memory, radiation hardened electronics, space environment, static memory drives, ReRAM, CID, Component Interface Descriptions

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AF141-251 TITLE: On-Orbit Reprogrammable Digital Waveform Generator for GPS

KEY TECHNOLOGY AREA(S): Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US

Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Develop an on-orbit reprogrammable digital waveform generator (ORDWG) for GPS satellites.

DESCRIPTION: The Global Positioning System (GPS) space segment is currently comprised of 31 satellites in a Medium Earth Orbit at an altitude of approximately 20,000km. Each satellite has an on-board waveform generator to create, combine and output several signals for terrestrial users to determine their geographic location and synchronize timing. These signals contain navigation data, Selective Availability (S/A) and Anti-Spoofing (A/S) capabilities, and Pseudo-Random Noise (PRN) codes to produce the appropriate signals for continual transmission.

The PRN codes are the Coarse Acquisition (C/A), Civilian (C), Encrypted Precision (P/Y), Military (M) codes, and Safety of Life (SoL) codes. These codes, when combined with the carrier frequency, are called Pseudo-Random Noise (PRN) because taken individually they look like noise. However, they are generated by a known algorithm and do repeat. For the C/A code, the PRN pattern repeats every millisecond, however, for the P(Y) code, the PRN pattern repeats every 267 days. The PRN pattern is unique for each satellite in order to allow the entire constellation to operate on the same frequencies. These codes are combined with a navigation message, which contains vehicle unique Telemetry, Clock, Ephemeris, and GPS constellation Almanac data.

The combined codes and messages are transmitted in several frequency bands: L1 (1575.42MHz), L2 (1227.60MHz), and L5 (1176.54MHz). The L1 frequency includes the L1C/A, L1C, L1P(Y) and L1M codes. L2 frequency transmission includes the L2C, L2P/Y, and L2M codes. The Safety of Life (SoL) codes are broadcast only on the L5 frequency band.

In addition, these waveforms contain two methods for denial of accuracy to civilian receivers: Selective Availability (S/A) and Anti-Spoofing (A/S). S/A is the injection of intentional errors into the waveform to decrease precision, while A/S uses an encryption method to decrease the likelihood of false signals. Waveform generation is becoming more complex as the GPS system matures with additional functions being added, anti-jamming routines changing, etc. Currently, there is no practical way to modify the waveform generation routine on-board the satellite.

There is a need to develop a digital waveform generator that can be reprogrammed only from the GPS Ground Control Segment with new waveform generation routines while the satellite is in orbit. This new ORDWG shall produce and be capable of modifying all current L1 PRN codes, be able to produce up to 10 different code signals, be able to change the navigation message data rates, combine the PRN codes and navigation messages with no losses or interference, and meet or exceed current applicable GPS specification requirements. This new waveform generator design should also include reductions in Size, Weight, Power, and Cost (SWaPC) to the greatest extent possible.

Proposals should clearly indicate how the result of the effort would be shown to improve the GPS system's capabilities through a test and validation plan. Testing and validation of risk reduction components of the overall effort in Phase I is encouraged.

Offerors are encouraged to work with PNT system prime contractors to help ensure applicability of their efforts and begin work towards technology transition.

Offerors should clearly indicate in their proposals what government furnished property or information are required for effort success. Requests for other-DoD contractor intellectual property will be rejected.

Radhard reqs for ORDWG:

Effect:	Units:	Level:
Total Ionizing Dose	rad(Si)	1e6
Single-Event Upset	Err/bit-day	1e10
Single-Event Latchup	None	None
Dose-Rate Upset	rads(Si)/s	1e10
Dose-Rate Survivability	rads(Si)/s	1e12

PHASE I: The resource constraints are 6 months and $150,000. Develop an On-Orbit Reprogrammable Digital Waveform Generator or conceptual design. This waveform generator can use radiation hardened reprogrammable logic, such as the Xilinx Vertex 5QV Rad Hard Field Programmable Gate Array (FPGA).

PHASE II: The selected company will design and build a brassboard or prototype On-Orbit Reprogrammable Digital Waveform Generator for ground test and evaluation. Phase II efforts should include ensuring compatibility with CID supporting overall payload &space vehicle reference designs as part of their commercialization effort. CID will be supplied to Phase I awardees invited to propose for Phase II.

PHASE III DUAL USE APPLICATIONS: The selected company will produce a space-qualifiable On-Orbit Reprogrammable Digital Waveform Generator. The company will support successful completion of the space qualification tests and transition of the waveform generator to production for inclusion in GPS satellites.

REFERENCES:

1. Blewitt, Geoffrey. "Basics of the GPS Technique: Observation Equations." Geodetic Applications of GPS. The Swedish Land Survey, 1997.

2. National Coordination Office for Space-Based Positioning, Navigation, and Timing. New Civil Signals. 06 February 2013. 19 March 2013.

3. Space Segment. 12 February 2013. 19 March 2013.

KEYWORDS: GPS, Digital Waveform Generator, Anti-Jam, Anti-Spoof, Selective Availability, CID, Component Interface Descriptions

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AF141-252 TITLE: Positioning, Navigating, Timing, Communications, Architecture, Mission Design

KEY TECHNOLOGY AREA(S): Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Create a revolutionary space-based architecture to better sustain U.S. military Global Positioning Systems in the 21st Century.

DESCRIPTION: The Global Positioning System (GPS) is a space-based satellite position, navigation, and timing system that provides position, velocity, and time in nearly all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. The system provides critical capabilities to military, civil and commercial users around the world. Advances in technology and new demands on the existing system have since led to efforts to modernize all three segments of the GPS system.

As effective as these advancements are, new concepts are needed for next-generation position, navigation, and timing (PNT) systems. GPS spectrum is increasingly congested, other nations have introduced alternative space-based PNT systems, and the vulnerabilities of GPS have become a liability as potential U.S. adversaries, terrorists, and criminal organizations seek to deny users access to the GPS signals.

In addition to the emergence of near-peer level PNT systems launched by other nations, the current GPS system carries with it several operational and sustainment challenges. Among these challenges are the high costs, susceptibility to jamming, and limited availability in many important environments. The primary cost driver for the GPS system is the need to maintain a worldwide constellation of satellites of ever-increasing complexity. Jamming vulnerability stems from the fact that GPS signals arrive about 20 dB below the noise floor. Limited availability occurs wherever the low-power signal is obstructed, such as indoors or underground, or in urban and natural canyons.

In recent decades, significant progress has been made in both terrestrial and space-based PNT technologies. The emergence of miniature inertial measuring units, chip-scale atomic clocks, and positioning using signals of opportunity have changed the way we think about the PNT problem. Smartphone systems are an example of emergent PNT, computing position using intelligent combinations of GPS, cell tower triangulation, Wi-Fi, and other systems such as GLONASS.

This topic area seeks solutions that can be extensions of the existing constellation and are compatible with existing GPS end-user hardware. Specific outcomes sought in this topic include:
- Reductions in sustainment costs for the GPS constellation
- Enhanced signal security
- Enhanced robustness of the constellation
- Reduced time to first fix
- Enhanced accuracy
- Enhanced canyon and urban canyon performance
- Reduced jammer susceptibility

Possible solutions for this topic area include but should not be limited to alternative constellation designs and orbital geometries, alternative frequencies, hosted PNT payloads on other space systems, and ground or space-based augmentations. Specific innovations at the component, subsystem, or payload level can be considered in this topic area to the extent that they enable fundamental changes in orbital configurations, architectures, or costs.

PHASE I: Design a revolutionary architecture to sustain U.S. military GPS systems. Develop concepts for deployed infrastructure (space, air, or terrestrial-based) and associated user equipment. Identify key functional performance parameters and associated enabling technologies required to realize conceived revolutionary approach. Deliver a credible technology development plan for Phase II effort(s).

PHASE II: Design and construct a limited operational system based on the work in Phase I and Phase II.

PHASE III DUAL USE APPLICATIONS: Design and construct a limited operational system based on the work in Phase I and Phase II. Military application: GPS/OCX follow-on system. Commercial application: Wide Area Augmentation System (WAAS).

REFERENCES:
1. National Research Council (U.S.). Committee on the Future of the Global Positioning System; National Academy of Public Administration (1995). The global positioning system: a shared national asset: recommendations for technical improvements and enhancements. National Academies Press. p. 16.ISBN 0-309-05283-1. Retrieved 2013-08-16., Chapter 1, p. 16.

2. Factsheets: GPS Advanced Control Segment (OCX). LosAngeles.af.mil. October 25, 2011.

3. National Positioning, Navigation, and Timing Architecture Final Report, National Security Space Office, September 2008.

4. Jaizki Mendizabal; Roc Berenguer; Juan Melendez (2009). GPS and Galileo. McGraw Hill. ISBN 978-0-07-159869-9.

5. The Future of the Global Positioning System, Defense Science Board, October 2005, p. 44 - 45.

KEYWORDS: Positioning, navigation, timing, Global Positioning System, GPS, PNT, RF, jamming, signals, denied, triangulation

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AF141-253 TITLE: Disruptive Military Navigation Architectures

KEY TECHNOLOGY AREA(S): Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Kristina Croake, kristina.croake@us.af.mil.

OBJECTIVE: Create a disruptive, fundamentally-new military navigation architecture to provide game-changing advantages for U.S. forces.

DESCRIPTION: GPS is a space-based satellite navigation system that provides location and timing information in many weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. The system provides critical capabilities to military and civil users. Advances in technology and new demands on the existing system have led to efforts to modernize the GPS system and implement the next generation of GPS III satellites and next-generation Operational Control System (OCX) (2). As effective as these advances are, new concepts are needed for next-generation position, navigation, and timing (PNT) systems. Relevant environments are congested, contested, and competitive and the PNT solutions will subsequently need to account for more difficult environment. Architectures are sought which have the promise of changing the value proposition for military users. Different physical processes are sought and approaches which profoundly change the cost, sustainment needs, vulnerabilities, performance levels, or operational constraints on users. Within this topic area, there is no need to meet the full suite of existing GPS program requirements. Performance requirements are specifically removed if the proposed solution promises one or more game changing variations in capability. Compromise on performance levels trading for fundamentally new capability may be considered in any area including accuracy, user hardware SWaP, all-weather 24-hour operation, or global coverage. To encourage more disruptive thinking, this topic area also removes the requirement to be backwards compatible with existing hardware and software and/or to be compatible with and interoperable with existing GPS constellations. Examples of game-changing capabilities should not be limited to but may include the ability to:
- Operate in a completely RF-jammed environment
- Operate without access to space assets
- Use existing natural or man-made radiation sources as fiduciaries.

There is no requirement in this topic area to include space-based assets but the use of existing or new space-based assets is permitted as an enhancement. Aerial, ground-based, sea-based and subterranean assets may be considered. Systems that work only for air, ground, sea, or space navigation or for only a subset of these will be considered if they provide other game-changing capabilities. Systems with minimal infrastructure cost needs are specifically desired, but exquisite capability requiring extensive infrastructure will also be considered. Systems that specifically

require access to the existing GPS system in order to function at all should not be proposed under this topic. Possible solutions for this topic include but should not be limited to:
- completely self-contained units that use a combination of natural and artificial radiation sources in combination with inertial measurement system,
- architectures that use multi-mode measurement of man-made and natural landmarks, airborne transceivers and timers,
- celestial navigation using optical or other forms of radiation, and
- modulation or passive measurement of other natural or artificial types of radiation, including acoustics, magnetic fields, Whistler waves.

We will consider the merits of any approach that has the prospect of reasonably near-term application and is based on well-established basic physical principles and technical means. Architectures with limited (special) applications and little or no global infrastructure will be considered as well as systems with regional or theater-level infrastructure needs. The use of signaling systems and modalities that are unexpected and/or undetectable and un-jammable is a possible positive feature.

PHASE I: Design a "Disruptive Navigation Architecture" based on feasible yet novel and disruptive technical approaches that revolutionize U.S. military navigation capabilities for the 21st Century. Identify key functional performance parameters and associated enabling technologies required to realize alternate navigation architectures. Deliver a credible technology development plan for Phase II effort(s).

PHASE II: Develop baseline performance and/or sustainment costs estimates that show advantages relative to the existing, evolving GPS-based architecture. Develop higher-fidelity, end-to-end architecture models, development roadmaps, and enabling component technologies for the proposed new disruptive navigation architecture.

PHASE III DUAL USE APPLICATIONS: Design and construct a limited operational system based on the work in Phase I and Phase II. This system may incorporate military GPS information (PRS, M Code), but should not rely on them, and be capable of operating when they are not available.

REFERENCES:
1. National Research Council (U.S.). Committee on the Future of the Global Positioning System; National Academy of Public Administration (1995). The global positioning system: a shared national asset: recommendations for technical improvements and enhancements. National Academies Press. p. 16.ISBN 0-309-05283-1. Retrieved 2013-08-16., Chapter 1, p. 16.

2. Factsheets: GPS Advanced Control Segment (OCX). Losangeles.af.mil. October 25, 2011.

KEYWORDS: Positioning, navigating, timing, Global Positioning System, GPS, PNT, RF, jamming, signals, denied, triangulation

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